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Cave Assessment, Monitoring, and Management Recommendations for Spirit Mountain Caverns, Bureau of Land Management, Worland District, Wyoming

October, 1979

Tom and Cathy Aley
Ozark Underground Laboratory

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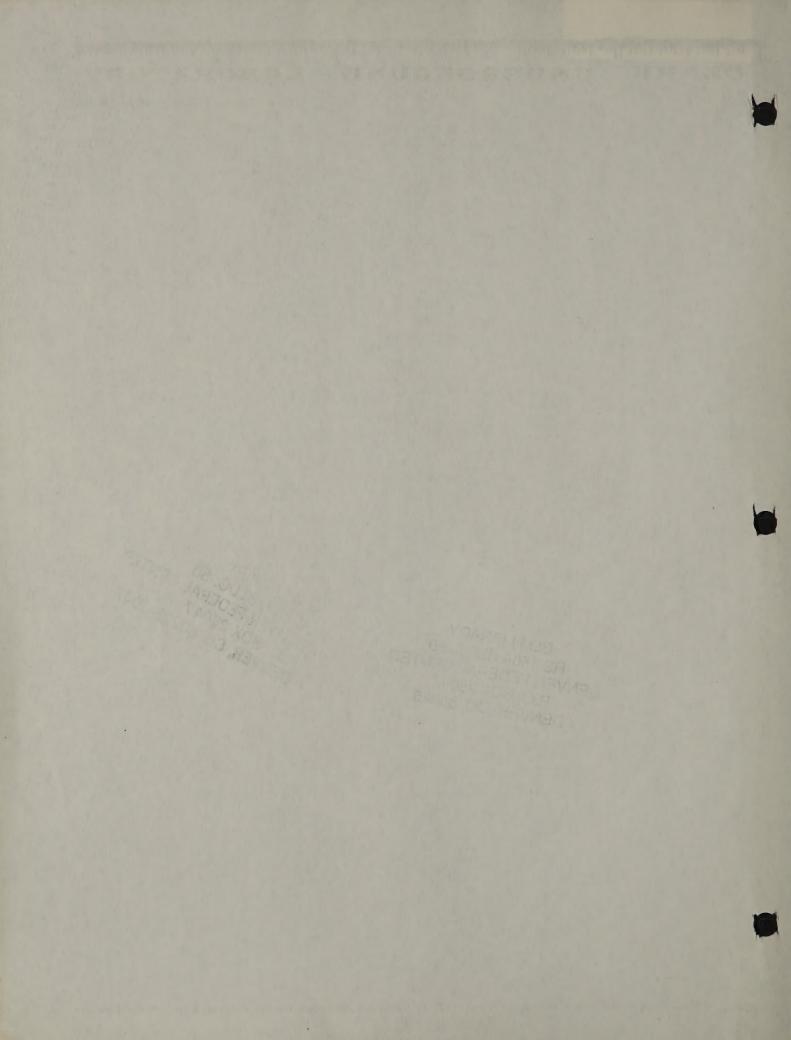
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EXECUTIVE SUMMARY

Spirit Mountain Caverns, formerly known as Frost Cave and Shoshone Caverns, is located on Cedar Mountain near Cody, Wyoming. It is one of the major caves of Wyoming and of the northern Rocky Mountain region of the United States. The cave is of state and regional significance for three reasons. First, it is a large cave with a lateral development of nearly a mile of passages and a vertical development of about 350 feet. Secondly, the cave contains significant geologic features. Thirdly, the cave provides significant opportunities for educational and recreational use.

Management conclusions and recommendations for Spirit Mountain Caverns are briefly summarized in the following paragraphs. Detailed discussions of rationale and justifications for these recommendations are found in the text of this report.

Commonly recognized cave hazards

- 1. People visiting any BLM cave should be cautioned about slippery walking surfaces, loose and shifting rocks, the possibility of becoming lost, and the need for carrying adequate lights, and the risk of falling off boulders or down pits.
- 2. Hazards associated with loose and shifting rocks in Spirit Mountain Caverns do not represent an unusually significant hazard.
- 3. The hazard of becoming lost is not unusually significant in Spirit Mountain Caverns.
- 4. Visitors to Spirit Mountain Caverns should be advised that the cave is of such size and complexity that good lights are needed. People planning to explore the cave should carry at least two sources of acceptable light.
- 5. BLM should make certain that parties registering to visit the cave have adequate lights.
- 6. Lighting requirements can be tempered by the nature of the visitation anticipated.
- 7. People visiting the cave should be cautioned about the two pits and one climb found in the cave, and should be advised of the equipment needed.

Histoplasmosis

- 1. The risk to visitors does not warrant the closure of the cave or the general restriction of access.
- 2. Visitors to the cave should be cautioned that <u>Histoplasma capsulatum</u> has been found in this cave, and that fecal material and dust should not be disturbed.
- 3. Visitors should be warned that the Pigeon Roost area and the route to this area are considered to be hazardous because of the fungus Histoplasma capsulatum and the abundance of pigeon feces, which provide a good substrate for this fungus.
- 4. A sign should be placed on the route to the Pigeon Roost area informing visitors that this is the area of the cave where the hazard of histoplasmosis is believed to be significant.
- 5. Histoplasmosis is a long term and uncorrectable situation which will always require at least some management attention.

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Alpha radiation

- 1. Alpha radiation should not be considered a significant health hazard at this cave.
- 2. Based upon measured alpha radiation concentrations, it is not necessary for BLM to caution visitors to this cave about cave radiation.
- 3. If additional radiation monitoring is done in this cave, sample station one should be deleted.
- 4. If personnel and funds are available, stations 2 through 12 should be monitored for alpha radiation during the summer of 1980 to develop baseline data.
- 5. If cool weather visitation is appreciable, it would be good to monitor stations 2 through 12 once during this period of the year.

Hydrogen sulfide gas

- 1. Hydrogen sulfide gas does not represent a major safety hazard in this cave.
- 2. If hydrogen sulfide gas is present in Spirit Mountain Caverns, it would most likely be detected during cold weather conditions.
- 3. Cave visitors should be cautioned that hydrogen sulfide gas has been reported in the cave.
- 4. Cave visitors should be particularly cautious if they smell any hydrogen sulfide gas.

Cave features and origin

- 1. Paleokarst and solution breccias have partially controlled the present location and orientation of cave passages.
- 2. More recent (Laramide age) tectonic activity created other routes within the rock mass through which water could pass.
- 3. Spirit Mountain Caverns was dissolved out by water.
- 4. The presence of extensive gypsum crusts in the cave indicates that geothermal activity has affected the cave.

Cave clean-up

- 1. Lumber and most other materials remaining in the cave from the time the cave was used as a show-cave should be removed.
- 2. The Log Pit area presents a special case; the logs in this area should not be removed.
- 3. Cans, bottles, and other trash should be removed from the cave.
- 4. The names, arrows, and other markings on the walls of the cave should be removed.
- 5. An archeologist could determine if signatures on the "signature rock" near Big Bridge should be removed or not.
- 6. Visitors should be specifically told not to litter or deface the cave and they specifically should be cautioned not to break or remove any natural materials in the cave.
- 7. Time estimates for cave clean-up are included in the text.

General Cave Management

1. Spirit Mountain Caverns is of both state and regional significance.

- 2. The cave cannot be restored to its pristine condition, but dramatic improvements can be made over present conditions.
- 3. Adequate protection of the cave will require that access to the cave be controlled.
- 4. A check-out procedure similar to that used for Horsethief Cave should be instituted for Spirit Mountain Caverns.
- 5. The road to the cave should be permanently closed at the point where it leaves the main dirt road leading to the top of Cedar Mountain.
- 6. The size and significance of the cave resource of the area may be increased by discoveries. Such discoveries can increase cave management concerns.

Additional investigations

- 1. One more set of alpha radiation measurements should be made in Spirit Mountain Caverns under warm weather conditions.
- 2. A moderately detailed search and rescue plan should be developed for Spirit Mountain Caverns.
- 3. Any caves administered by BLM in which hydrogen sulfide gas is detected should be monitored, and the safety hazard should be evaluated.
- 4. Any newly discovered caves on BLM lands in the vicinity of Spirit Mountain Caverns should be assessed both for their features and for safety and management considerations as soon after discovery as possible.
- 5. If people visiting Spirit Mountain Caverns in cold weather periods report the odor of hydrogen sulfide gas within the cave, monitoring of the concentrations should be conducted during cold weather conditions and the possible hazard should be evaluated.
- 6. Mineral samples taken from Spirit Mountain Caverns are being evaluated by our minerologist and results will be included in an addendum to this report. Should unique features be identified in the specimens, additional evaluation might be desirable.
- 7. If appreciable cave use occurs during cold weather periods of the year, one set of alpha radiation measurements should be made during this period.

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LOCATION OF CAVE ENTRANCES

Spirit Mountain Caverns is located in Section 5, T52N, R102W, Park County, Wyoming. The cave is about 3½ miles west of Cody, Wyoming, and can be reached by a rough and steep road which turns off U.S. highways 14, 16, and 20 in Section 4, T52N, R102W; this road leads to the top of Cedar Mountain. There is a locked gate on this road about 1,000 feet from the highway; a key can be obtained from the BLM office in Cody.

There is only one major intersection on the rough and steep road up Cedar Mountain. This intersection is located at an elevation of about 6,400 feet. From this intersection, the northern-most road leads to a small turn-around area about 200 feet from the main entrance to Spirit Mountain Caverns. The approximate elevation of this entrance is 6,300 feet. Figure 1 is a photograph of this entrance, and shows the present gate.

Two additional entrances to Spirit Mountain Caverns are located about 900 to 1000 feet northwest of the main entrance. The additional entrances are shown on the enclosed map, and are immedately adjacent to each other. These entrances provide access to the Pigeon Roost section of the cave. Reaching these entrances requires a 50 to 60 foot vertical descent from the top of the Madison limestone cliff. The drop from the top to the bottom of the cliff is 175 to 200 feet. Figure 2 is a view of these entrances.

These two additional entrances to Spirit Mountain Caverns are not visible from the main entrance, nor from any of the roads leading to the cave. It is unlikely that the casual visitor to the cave would accidentally find them.

LAYOUT OF THE CAVE

Figure 3 is a map of Spirit Mountain Caverns; the map is reproduced from the Wyoming Geological Survey publication "Caves of Wyoming" (Hill et al., 1976). This map is generally accurate, although there are unmapped rooms and passages located beneath the lowest "level" mapped in the cave. On the map in Figure 3, entry to these passages is indicated on the rough cross section by the open lines at the bottom of the cave.

Spirit Mountain Caverns is basically a three dimensional maze of passages. Pits and steeply inclined passages integrate "levels" of the cave. The "levels" identified on the existing map of the cave are helpful in visualizing the nature of the passages, but they are not truly "levels" in an elevational sense. This can readily be seen by looking at the rough cross sectional view shown in Figure 3.

On the existing map it is sometimes difficult to readily separate one "level" from another. To aid in this separation, we have prepared a series of maps upon which we have shaded in each of the identified levels with a different color. We believe this will give the land manager a better grasp of the layout of the cave. These maps are included as Figures 4 through 7.

The uppermost level in the cave consists of passages in the Pigeon Roost area and passages at the top of Credibility Gap. These areas are shaded in green, and are shown in Figure 4.

There are two separate routes to the Pigeon Roost area. The first route is to enter the cave at the main entrance, and to then follow the main passage until you are 150 feet from the gate. At this point there



Figure 1. The main entrance to Spirit Mountain Caverns.

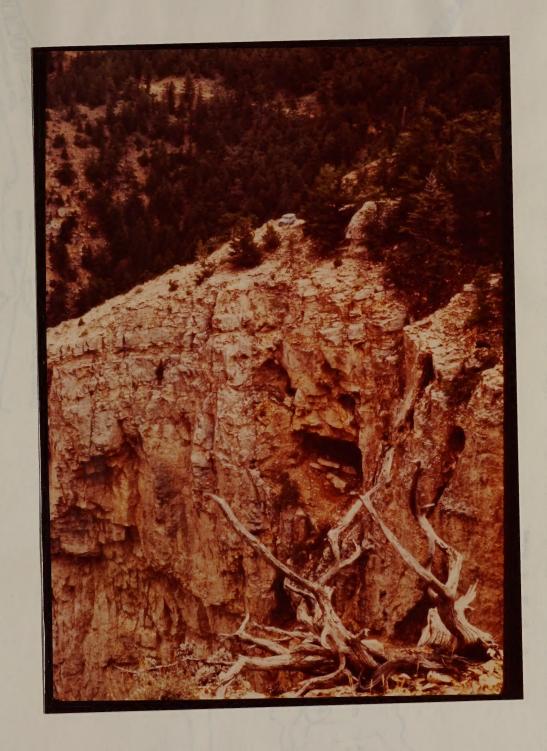


Figure 2. The Pigeon Roost entrances to Spirit Mountain Caverns. The large opening is the principal entrance into this area. The blue vehicle in the background is parked at the end of the road leading to the cave, and is about 200 feet south of the main entrance.

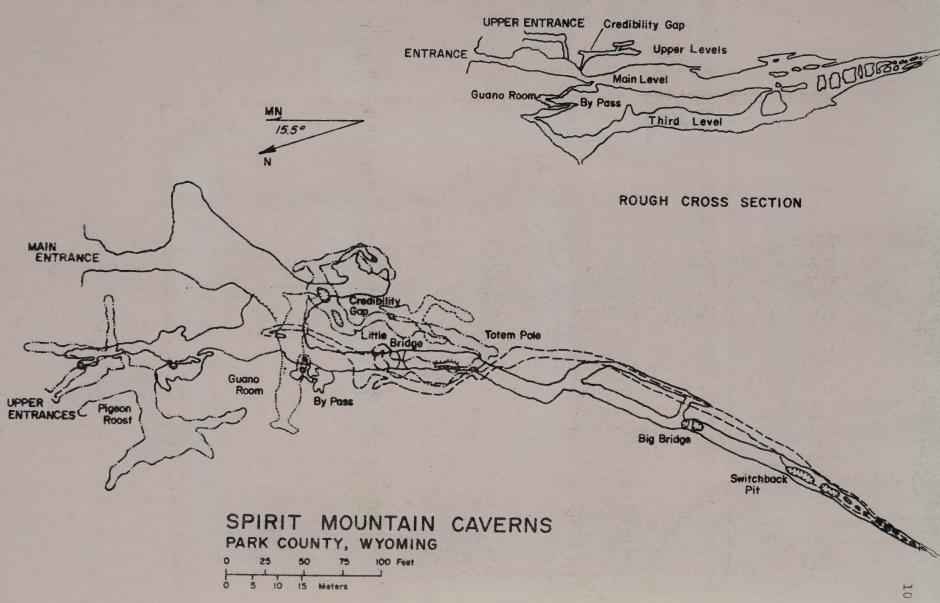


Figure 3. Spirit Mountain Caverns. Map from Hill et al., 1976; Wyoming Geological Survey

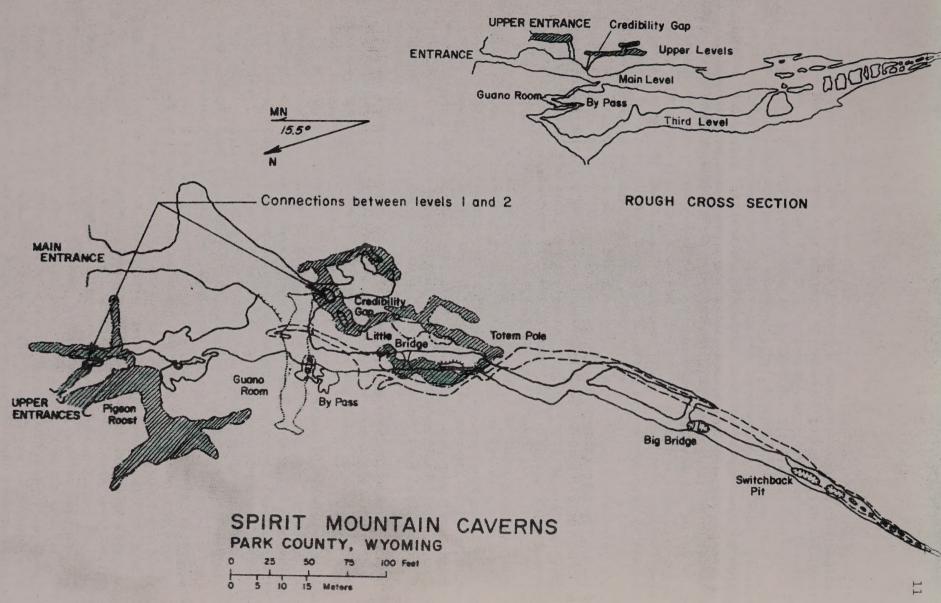


Figure 4. Level 1 (the uppermost level) of Spirit Mountain Caverns.

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is a major side passage leading upward to the right (north). Follow this passage to the NNE and upward through some dusty crawls and small rooms. The point where this network of passages connects with the uppermost level is indicated on Figure 4 by the notation "connection between levels 1 and 2". Under most weather conditions, a breeze can be felt moving through the connecting passage. The connection passage is a small crawlway which periodically requires re-excavation of dust, packrat debris, and pigeon feathers and droppings in order to make entry possible (to be discussed under health and safety considerations).

The second route to the Pigeon Roost area is to enter the cave through the upper entrances. One can traverse along the top of the cliff of Madison limestone from near the end of the cave road to a point directly above the additional entrances. From this point, rope or cable ladders, or other vertical caving or climbing techniques, can be used to enter the upper entrances to the cave.

The Pigeon Roost Area of the cave is presently heavily used by the pigeons which frequent the Cody area during the daytime. We did not attempt to estimate the population size, but after viewing the amount of pigeon guano in the area, and seeing and hearing the pigeon activity near the roost, it is possible that a large portion of the pidgeon population of Cody frequents this entrance to Spirit Mountain Caverns.

Passages at the top of Credibility Gap must be entered by climbing about 80 feet up Credibility Gap. From the gate on the main entrance to Spirit Mountain Caverns, it is 120 feet to the intersection of a major and obvious passage on the left wall of the main passage. This side passage is about 10 feet above the floor of the main passage. The Credibility Gap climb begins about 15 feet from the intersection of these two passages; there are two calcite columns about three feet in diameter at the base of the climb.

The chambers at the top of Credibility Gap consist of small rooms and crawlways. The extent of these passages is adequately depicted on the map in Figure 4. As illustrated by the map, this is a relatively small portion of the cave.

The second (or main) level of the cave is shown in Figure 5 and is shaded in orange. Entry to this level is through the main entrance. About 60% of the formerly developed tourist route through the cave was on this level. Figure 5 shows two points which connect this level with the upper level (level 1), and three points which connect the main level with the underlying level (level 3). The routes connecting levels 1 and 2 have already been discussed; the connections between levels 2 and 3 will be discussed in the following paragraphs.

The first connection between levels 2 and 3 is the Guano Room Bypass route which is shaded in red on Figure 6. From the gate at the cave entrance, it is approximately 160 feet to the entrance of the Guano Room Bypass. The entrance to the Bypass route is a pit about 12 feet deep on the west wall of the cave. The diameter of this pit (which we will call the Log Pit) was reduced by trail construction in the main level of the cave. During this construction, large logs were placed across the pit. On top of these, smaller logs were placed at right angles; rock and dirt were placed on top of the smaller logs. The climb down the Log Pit is easy; care should be taken not to disturb any of the rocks or logs which support the trail in the main level of the cave. There is a small room at the base of the Log Pit. From this room, an obvious, short crawlway leads to a second room about the same size as the first room. A crawl-

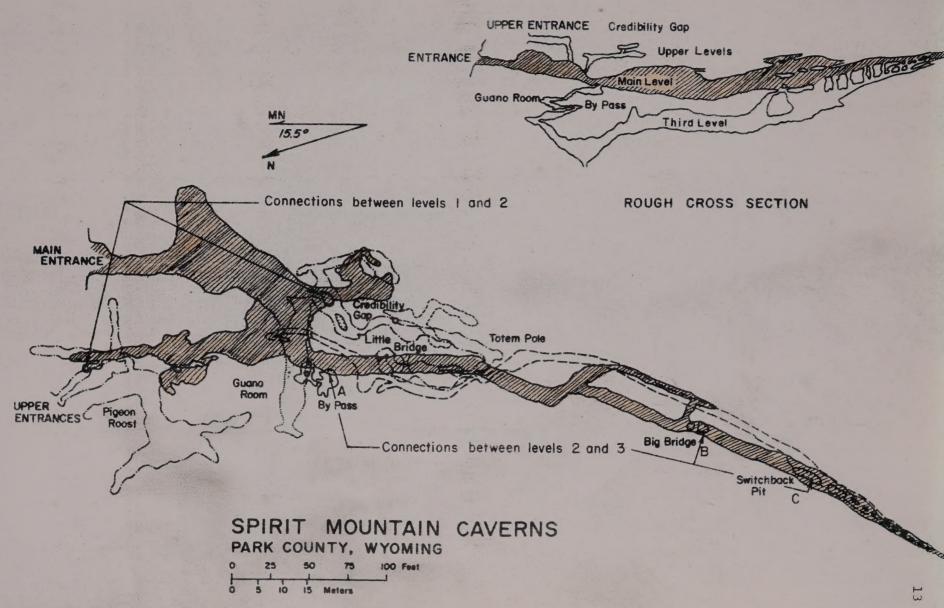


Figure 5. Level 2 (the main level) of Spirit Mountain Caverns.



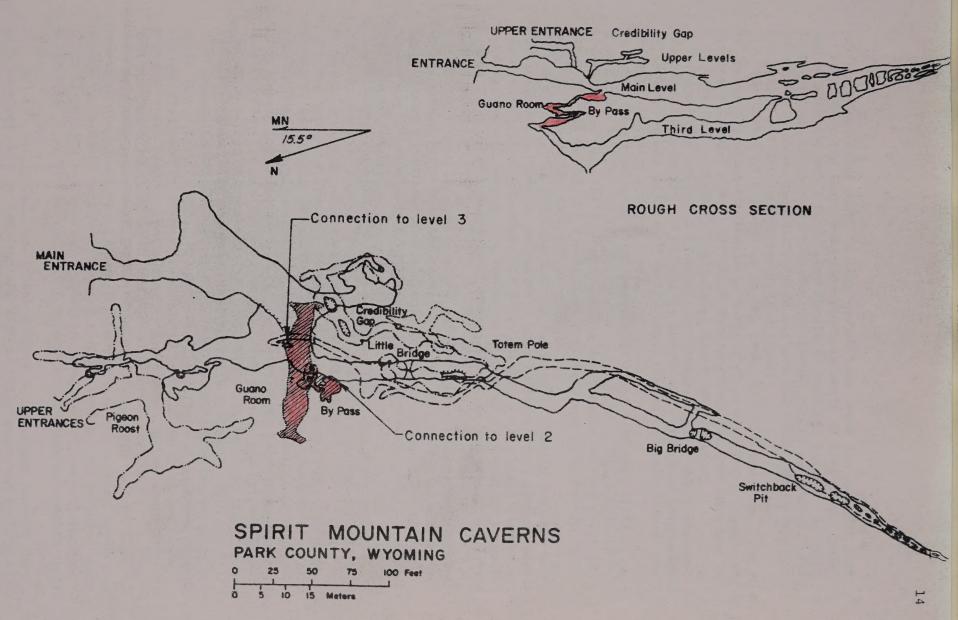


Figure 6. Passages on the Guano Room Bypass Route between levels 2 and 3.

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way near the lowest point in this second room leads (in about 20 feet) to the top of the Guano Room Pit, which is about 40 feet deep. This pit can be climbed, but a belay rope should be used for safety. In order to properly anchor the rope, minimum rope length should be 80 feet. Safety considerations for negotiating this pit will be discussed in detail in the health and safety section of this report.

The bottom of this pit is on the floor of the Guano Room. The room is apparently named for the large amounts of packrat feces (guano) which are found in this area. The Guano Room is about 180 feet long and 15 feet wide, and contains a substantial amount of breakdown.

An obvious and major fissure-like passage leads steeply downward from the Guano Room. One can easily and safely climb down this passage for about 50 feet to level 3 of the cave. Entry to level 3 is at the northern extremity of this level.

The second connection between levels 2 and 3 is identified as point B on Figure 5. This is Big Bridge Pit. At present, there are old steps and platforms from the former show-cave development at this point in level 2. Big Bridge Pit is about 45 feet deep and is about 400 feet from the gate on the main entrance.

Big Bridge Pit requires a belay for safety. During our work in Spirit Mountain Caverns, we rigged a rope ladder in this pit for assistance in climbing. However, the route can be fairly easily climbed with a belay rope for safety. Of the three routes we will discuss between levels 2 and 3, this connection (Connection B) is the easiest, quickest, and safest.

Connection C between levels 2 and 3 (Figure 5) involves a descent of Switchback Pit. When the cave was open to the public as a show cave, the stairway connecting levels 2 and 3 descended through Switchback Pit and made a 180 degree turn within Switchback Pit (this probably explains the name of the pit).

Although Switchback Pit was a logical route for a stairway, it is not a good route between levels 2 and 3 without a stairway. Connection B, which is nearby, is a much more reasonable route.

The third (or Crystal) level of Spirit Mountain Caverns is shown in Figure 7, and is shaded in blue. Most of this level consists of tall fissure-like passages. Figure 7 shows connections with level 2 (which have already been discussed). Figure 7 also shows three connections with level 4. Level 4 has not been mapped. The connections between levels 3 and 4 are rather obvious passages descending from level 3; their locations are shown on Figure 7 and need no further description.

Level 4 consists of a number of small rooms and passages, many of which are interconnected. When one first enters these passages he gets the impression of entering a maze system in which he could get lost. However, there are not really that many passages, and it would be difficult to remain lost for more than half an hour.

We do not believe that level 4 of Spirit Mountain Caverns needs to be mapped for management purposes. The passages are neither significant enough nor complex enough to require this attention. We estimate that there is perhaps 600 feet of passage in level 4, and that it descends to a depth of 50 or 60 feet below the deepest point presently mapped in the cave.

Hill et al. (1976) report "the deepest point mapped beneath the main entrance is -199 feet and the highest point above the surface station is +89 feet, giving the cave a total vertical extent of 288 feet."

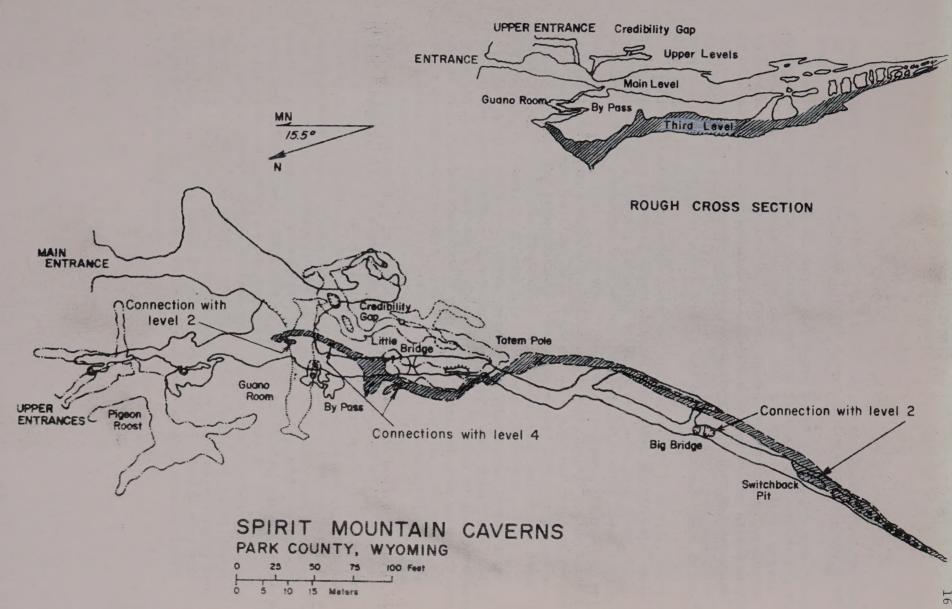


Figure 7. Level 3 (the crystal level) of Spirit Mountain Caverns.

These values excluded level 4, thus the total vertical extent of the cave is 340 or 350 feet. The total lateral extent of the cave is about 4,600 feet.

Legends and rumors of lost passages are often associated with caves which have been known for a number of years. Spirit Mountain Caverns is no exception. Deep levels of the cave, some containing sulphur gases, have been reported. Hill et al. (1976) added credence to the existence of extremely deep cave passages by publishing a copy of the Nelson sketch map of Spirit Cave (Spirit Mountain Caverns). The Nelson map (which we have copied from Hill et al., 1976) is shown as Figure 8. It indicates that the cave consists of eight levels, and has a vertical depth in excess of 1100 feet.

We have examined both the cave and the Nelson Map in detail, and believe that we have seen all eight of the levels shown on his map. Nelson's level 1 is obviously the main level of the cave (our level 2). Nelson's level 3 resembles what we have called the crystal level (our level three). If this is the case, then where is Nelson's level 2? We believe this can be answered by descending the Big Bridge Pit at Point B in Figure 5. About half way down this pit is a distinct ledge which persists laterally for some distance. We believe this ledge is Nelson's level 2. If this is the case, then the ladders which Nelson has shown connecting his levels 1, 2, and 3 are reasonably accurate.

In Figure 7 we showed three connections between our levels 3 and 4. The southernmost of these connections leads into what Nelson has called the Frost Room. This room is apparently named in honor of the discoverer of the cave, Mr. Ned Frost. Although Nelson does not show it on his map, the Frost Room connects with some of his lower levels.

Nelson's level 4 is, we believe, the northernmost portion of what we have shown in Figure 7 as the third level of the cave. Immediately north of the end of the Tourist Route Pit (see Figure 7) the passage drops steeply; this is indicated in the cross-section of the cave as shown in Figure 7. If we are correct in our interpretation of the location of Nelson's level 4, then the rest of his sketch map fits the passages we have seen. If one descends from our level 3 to our level 4 via the northernmost route shown on Figure 7, he will pass through several small rooms and negotiate several small climbs. There are sufficient rooms and climbs along this route to account for Nelson's levels 5 through 8; all of these levels are incorporated in our level 4.

We are convinced that we have seen all the passages which Nelson shows on his map, and that he greatly over-estimated the total vertical extent of the cave. Instead of the depth below the entrance being over 1100 feet, it is only about 250 or 260 feet. Still, this a very substantial vertical drop, and it is very easy to greatly over-estimate vertical drops underground.

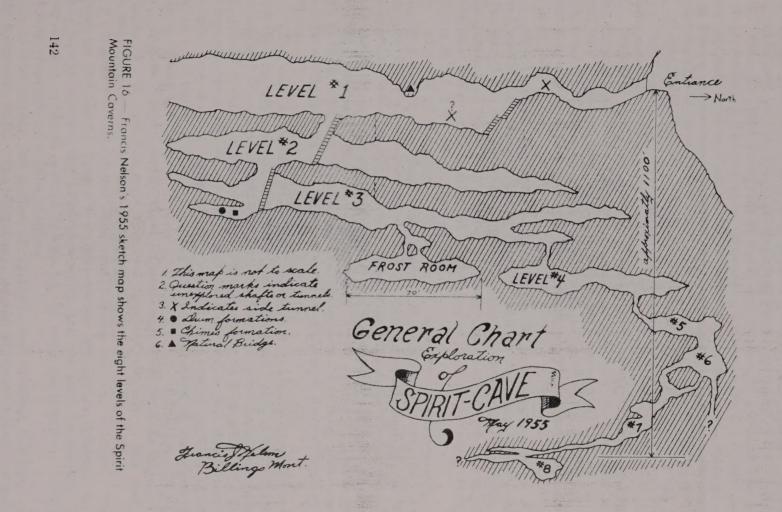


Figure 8. The Nelson sketch map of Spirit Mountain Caverns. From Hill et. al., 1976; Wyoming Geological Survey.

DESCRIPTION OF CAVE FEATURES AND VALUES

Spirit Mountain Caverns is one of the major caves of Wyoming and of the northern Rocky Mountain Region of the United States. The cave is of state and regional significance for three reasons.

First, within this region caves are generally uncommon features. Spirit Mountain Caverns is a large cave system, with a lateral development of nearly a mile of passages, and a vertical development of about 350 feet. Based upon its size alone, the cave is a regionally significant feature.

Secondly, the cave displays a complex history of solutional activity. Some facets of this history are common to the region, while others are rare.

Thirdly, the cave provides significant opportunities for educational and recreational use. Not only does the cave possess features of interest, but these features are also reasonably accessible (which is in distinct contrast to many other caves in this region). In addition, the cave has a reasonably large carrying capacity for educational and recreational use.

Spirit Mountain Caverns, located on Cedar Mountain over a thousand feet above the Shoshone River and the town of Cody, has a very attractive setting. The quality of the setting has been recently improved by the removal of old steps and lumber remaining from the time when this cave was open to the public as a show cave. The picturesque setting adds to the natural values of the cave.

Level 1 of the cave (see Figure 4) consists of two segments. The Pigeon Roost area includes two immediately adjacent cliffside entrances through which pigeons enter the cave. Under certain weather conditions, some odors from the pigeons can be smelled elsewhere in the cave. Pigeons roosting in the cave are certainly a unique feature of this cave, yet they are not a beneficial feature. To the contrary, pigeon use of the cave creates possible human health impacts, and thus increases cave management problems (see "Histoplasmosis and other lung diseases" in this report).

The second segment of level 1 (Figure 4) lies at the top of the Credibility Gap climb. This area includes some calcite speleothems (primarily stalactites and columns) as well as some excellent displays of gypsum crust. Unfortunately, careless cavers have muddied a substantial amount of the gypsum crust in this area, thus degrading its natural appearance. However, the area at the top of Credibility Gap is still reasonably attractive. This is the only area of the cave where there is any moisture.

The second (or main) level of the cave (Figure 5) is easily accessible. It is also the most spacious level of the cave. The spaciousness is well illustrated by the photographs in Figures 9 and 10.

The main level of the cave contains two natural bridges. These are shown on the map in Figure 5 as Big Bridge and Little Bridge. Both of the natural bridges are limestone which has not been dissolved. Of the two natural bridges, Little Bridge is the more spectacular. Figure 9 is a photograph of Little Bridge.

Little Bridge has a span of 12 feet, and is about six feet wide at its narrowest spot. Its thickness, at the thinnest point, is four feet. There are some slabs of breakdown on the top of the bridge, and some nice gypsum crust in small pockets and alcoves under the bridge.



Figure 9. Little Bridge in Spirit Mountain Caverns.





Figure 10. The Totem Pole (a large slab of rock which hangs over the main passage).

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Big Bridge is located above Big Bridge Pit (which connects levels 2 and 3). A photograph of Big Bridge is included in the brochure used when the cave was open to the public (see Appendix A).

Figure 10 is a view of the Totem Pole, which is found on the main level of the cave. The Totem Pole is a large slab of limestone which has detached from the wall. It is about 30 feet high, 25 feet long, and up to eight feet thick. It has hinged away from the wall, with the hinge point being near the floor. At the top of the slab, the gap between the slab and the wall is six feet, while there is hardly any gap at floor level. The top of the slab leans against the opposite wall of the cave, and thus is in no danger of falling.

The Totem Pole probably derives its name from its shape and from the irregular lines of gypsum crust which can be particularly well seen at the northern end of this slab of rock. Figure 10 is taken from south of the Totem Pole. A photo of the north side of the Totem Pole is on the cover of the old show-cave brochure (Appendix A).

Some of the most interesting features in the main level of Spirit Mountain Caverns are found in alcoves and wall pockets. Figure 11 shows a large patch of colorful mineralization located adjacent to the former trail route near Big Bridge. Figure 12 shows gypsum crust and small gypsum stalactites in another wall alcove. In other places, there are wildly convoluted lines on passage walls resulting from the exfoliation (or human removal) of pieces of gypsum crust (Figure 13).

A final feature of interest in the main level is two calcite columns about 3 feet in diameter and 10 feet tall located at the base of the Credibility Gap climb. They are the largest calcite formations found in the cave. It is unfortunate that the climb up Credibility Gap goes directly up these columns, since this climbing has scarred and dirtied these formations.

The third (or crystal) level of the cave is shown in Figure 7. This area consists primarily of high fissure-like passages. Most of the walls are covered with thick deposits of nearly white gypsum crust (Figures 14 and 15), which sometimes include many small gypsum stalactites. In one area (under a ledge) large calcite dog tooth spar crystals are found and in other areas large, clear, calcite crystals are lying about.

The crystal level of Spirit Mountain Caverns is the most beautiful level of the cave, and is an impressive area. The gypsum crusts on the walls are at least several inches thick. In some places where the gypsum crusts have separated from the wall one can see even more gypsum behind the crust. Gypsum is also found on some blocks on the floor. In one place, drippage from the ceiling has formed a solutional flute about an inch in diameter and a foot long in a block of gypsum on the cave floor.

The 4th level of the cave has not been mapped, but we estimate that it contains about 600 feet of passages and small rooms. Many of the larger rooms contain breakdown, and travel through the area involves some small climbs and many crawlways. This area includes some good displays of gypsum crust, but the crust is not nearly as extensive as that found on the 3rd level. The area also includes localized calcite deposits. Most of these deposits are old flowstone, although there is also some dog tooth spar and some highly recrystalized former stalactites found in the area.

Another important and interesting feature warranting attention is the origin and natural development of Spirit Mountain Caverns. In other words, related questions are "why is the cave here" and "why does it look as it does?"

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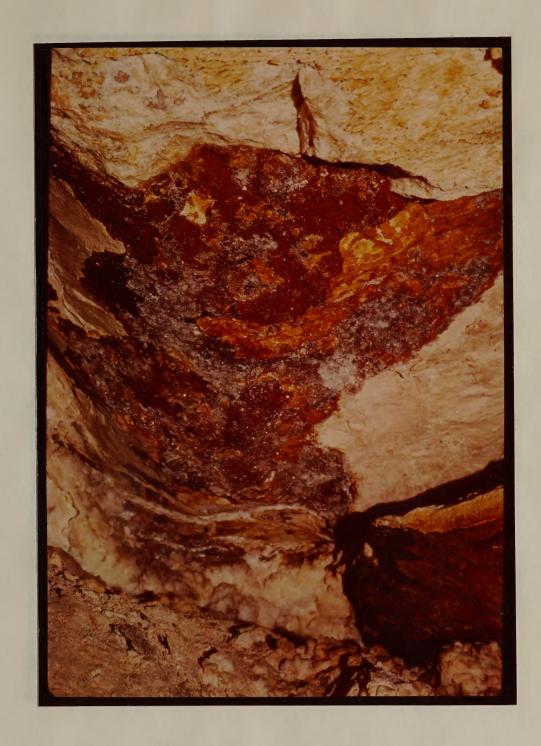


Figure 11. Colorful iron mineralization on the cave ceiling near Big Bridge.



Figure 12. Gypsum crust and small gypsum stalactites in a wall alcove.

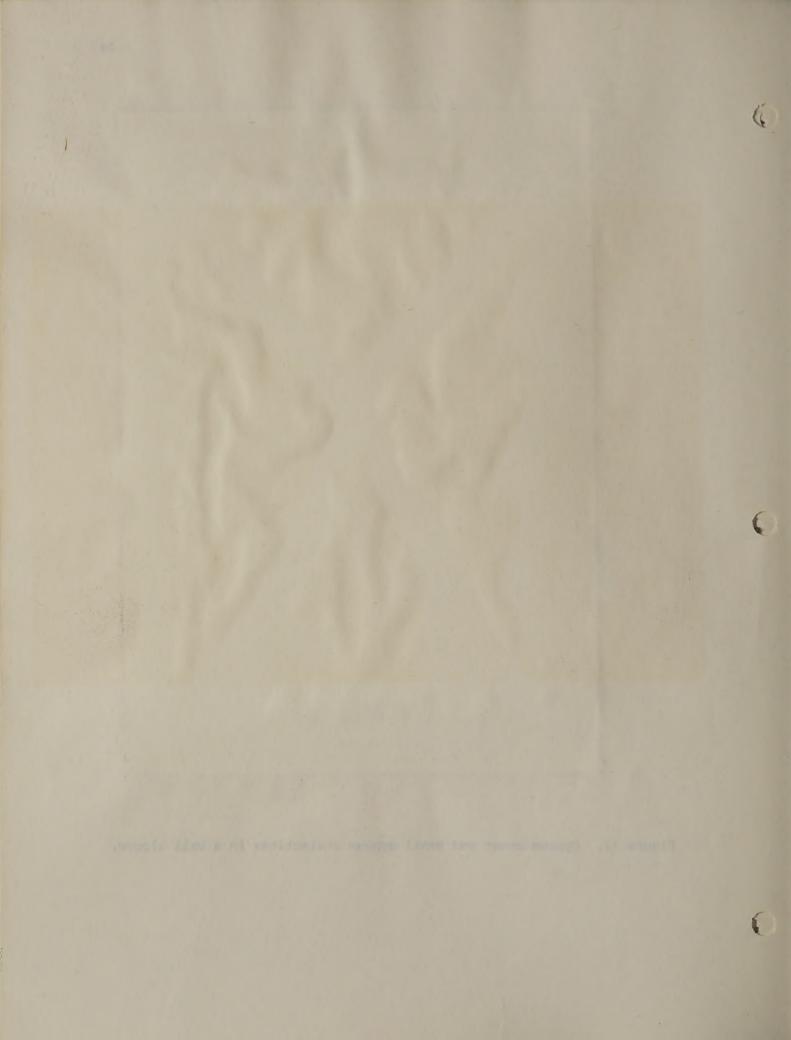




Figure 13. Convoluted lines on passage walls from exfoliation or removal of gypsum crust.

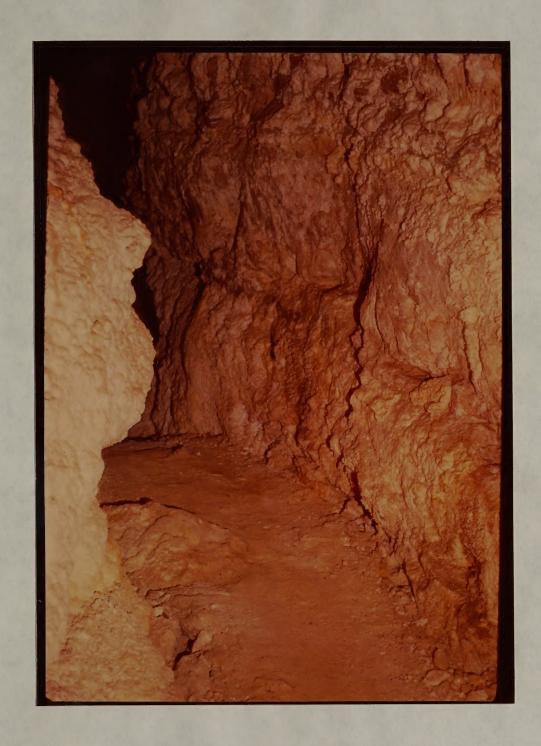
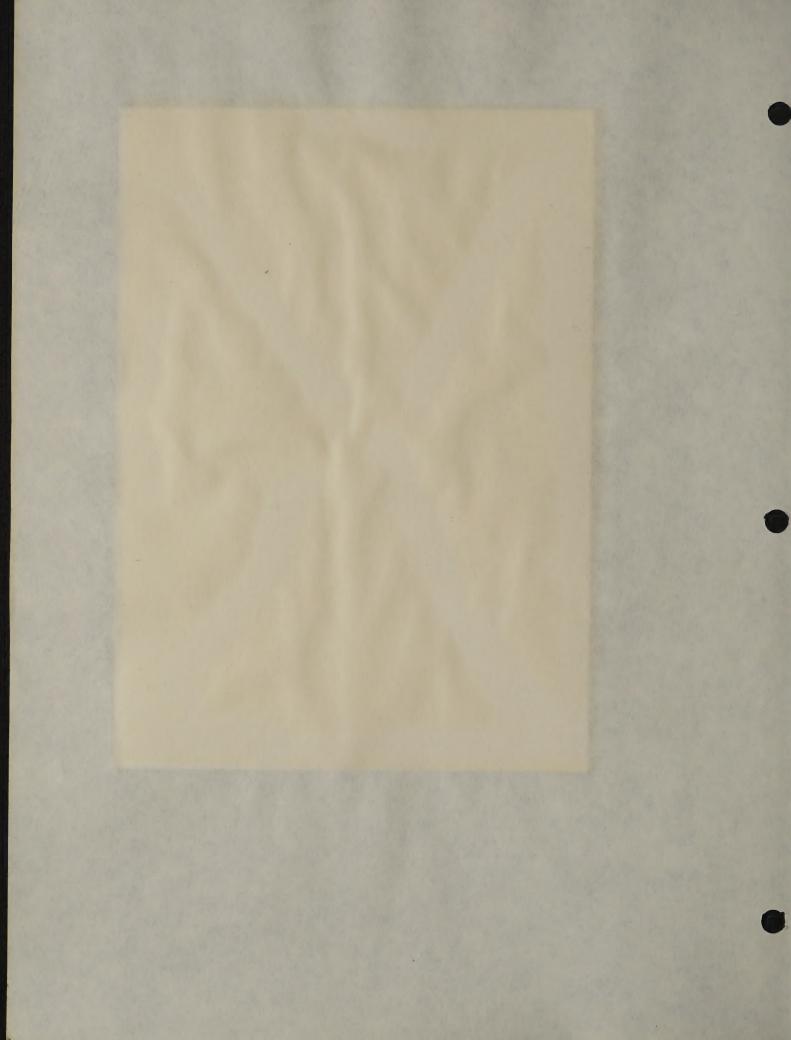


Figure 14. Cave walls coated with gypsum crust on level 3. The former tourist trail passes through this area.



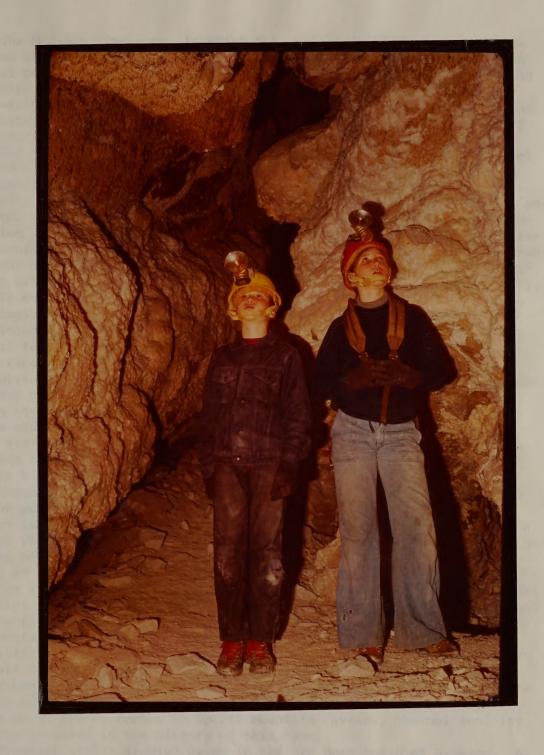


Figure 15. A typical passage in level 3 of Spirit Mountain Caverns.

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The Madison limestone, in which the cave is located, is of Mississippian age. After these beds of limestone were deposited there was an initial period of karst development which produced sinkholes, caves, and extensive subsurface drainage. This karst development occurred before the overlying geologic units were deposited. This karst development has been discussed in detail by Sutherland (1976), McEldowney et al. (1977) and numerous other authors.

The initial karst development (about 300 million years ago [Hill et al., 1976]) resulted in the development of substantial cavities within the limestone as well as within evaporite deposits. Evaporite sequences typically include potash and magnesium salts, rock salt, and gypsum or anhydrite. These deposits are more soluble than limestone, thus extensive solution of the evaporites would be anticipated. With extensive solution in evaporite beds, much of the overlying limestone subsided and collapsed into the solutional cavities. This formed the regionally persistent solution breccia 10 to 50 feet thick within the Madison (McEldowney, 1977).

It seems likely that solutional passages within the Madison became hydrologically well integrated during this period of karst development. The landscape at that time on top of the Madison limestone was probably similar to the sinkhole karst landscape now found in Florida. In the subsurface, there were many caves.

Ultimately, the Madison limestone was resubmerged. With this resubmergence came sediment filling of the existing solutional cavities. Within the upper two levels of Spirit Mountain Caverns one can see many of the old fills and solution breccias which date from this period. These are paleokarst features. An important point to remember when considering this cavity filling is that, in general, a hole is never completely filled.

Tectonic activity in more recent Laramide time (beginning about 70 million years ago) resulted in major fracturing and folding within the Madison limestone. In addition to developing fractures in the limestone through which water could pass, the tectonic activity probably also helped develop new pathways through some of the paleokarst cavity fills (McEldowney et al., 1977).

The area around Spirit Mountain Caverns has also experienced thermal activity; there are still sulfur vents near the base of the mountain, and as recently as 100 years ago thermal springs discharged from the base of the mountain. It seems likely that thermal activity and/or limestone dissolution by sulfuric acid have been involved in the history of Spirit Mountain Caverns.

Caves which have been developed or modified by thermal activity are rare in the United States; Wyoming has several. Based upon the gypsum crusts which are so common in Spirit Mountain Caverns, thermal activity has been involved in the history of this cave.

Egemeier (1973) studied caves in the Big Horn Basin of Wyoming. As a part of his study, he developed a convincing explanation for the gypsum crusts such as those in Spirit Mountain Caverns. Basically, the air in geothermal caves contains hydrogen sulfide gas. Much of the hydrogen sulfide in the thermal waters escapes into the cave air. Some of this redissolves in water drops on the cave walls, where it is oxidized by dissolved oxygen in these droplets. This produces sulfur and sulfuric acid. When sulfuric acid attacks limestone, it converts it to gypsum. Gypsum formed in this manner produces a crust on cave walls and ceilings.

In Spirit Mountain Caverns, we noted that the gypsum crust often appeared to be related to the bedding of the limestone beneath it. This is precisely what would be expected in a conversion of limestone to gypsum; similar occurrences in other Wyoming caves were discussed by Egemeier (1973).

Chemical comparisons of trace elements could be made between the gypsum crust and the immediately adjacent limestone beds to verify that the majority of the gypsum crust in Spirit Mountain Caverns was indeed due to the conversion of limestone to gypsum through the action of sulfuric acid. This would be an interesting research project for someone and would add to our interpretive knowledge of Spirit Mountain Caverns. However, in the absence of such work it seems likely that much or most of the gypsum crusts found in Spirit Mountain Caverns have resulted from the interaction of hydrogen sulfide gas, oxygen, and droplets of water on cave walls and ceilings.

We believe that that the cooling of underground air as it moved upward from deep thermal sources would have resulted in substantial water condensation on cave walls; it would not have been necessary for thermal springs to flow through cave passages or to discharge from the cave. In fact, considering the highly soluble nature of gypsum in water, the abundance of thick gypsum crusts in Spirit Mountain Caverns is strong evidence that thermal waters did not discharge from the cave at the time that the gypsum crust was formed.

In summary, we can draw four conclusions about why the cave is here, and why it looks as it does.

First paleokarst and solution breccias have partially controlled the present location and orientation of cave passages. We believe that much of the three dimensional maze nature of the cave is related to the influence of paleokarst and solution breccias. Some of the places which were solutional cavities many millions of years ago (and were subsequently filled with other sediments) are cavities again.

Secondly, more recent (Laramide age) tectonic activity created other routes within the rock mass through which water could pass. Much of the travel route on the crystal level of the cave traverses a high, fissure-like passage. The joints along which this passage was developed are very likely of Laramide age.

Thirdly, Spirit Mountain Caverns was dissolved out by water. In places, passages have been modified by breakdown, yet it is important to remember that the cave is a solutional feature. Major solutional enlargement of the cave may well have occurred when the elevation of the channel of the Shoshone River was near that of the cave. However, we can find no evidence to indicate that this was indeed the case; it is possible that much of the cave enlargement occurred more recently.

Fourth, the presence of extensive gypsum crusts in the cave indicates that geothermal activity has affected the cave. This does not mean that geysers or hot springs have ever discharged from the cave; we could find no evidence that this has occurred. It does appear, however, that warm or hot air containing hydrogen sulfide has circulated through the cave from deep sources. Oxidation of hydrogen sulfide produces sulfuric acid, which converts limestone into gypsum. It is our opinion that much of the extensive gypsum found in all levels of this cave is derived from this process.

In view of the features and geologic history found in Spirit Mountain Caverns, it is obvious that the cave is of educational value. The

main level of the cave, which is readily accessible, contains examples of essentially all of the important geologic features found in the cave. The crystal level of the cave, which requires some equipment and experience to visit, contains extensive deposits of gypsum cave crust.

Spirit Mountain Caverns is also of substantial recreational value. Although the cave may be less appealing to dedicated cavers than Horsethief or La Caverna de Tres Charros, it is our conclusion that Spirit Mountain Caverns has substantial appeal to visitors with somewhat less cave experience. Furthermore, we enjoyed the cave, and we have substantial cave experience.

A number of factors contribute to the recreational appeal of Spirit Mountain Caverns. First, the trip up the mountain to the cave is enjoyable, and the setting of the cave is beautiful. Secondly, the cave is complex and has enough diverse features to make exploration fun and rewarding. The typical visitor to the cave would leave with the impression that he had not seen all of the passages which exist. This is an important feature in cave visitor satisfaction. Thirdly, the cave contains challenges and hazards which make exploration an exhilerating adventure. Although it is possible that some of the hazards could result in injury to people exploring the cave, the hazards which exist are not generally treacherous in nature. Use of adequate equipment and techniques can protect visitors from the hazards which exist. These hazards are discussed in detail in the health and safety section of this report. Finally, even though the cave has suffered substantial vandalism, there are still natural features in the cave which are well worth seeing.

HEALTH AND SAFETY

Four classes of health and safety hazards may be associated with visitation of Spirit Mountain Caverns. The first catagory includes those hazards people commonly recognize as associated with cave exploration; these include hazards of loose rocks, the chance of falling down holes, and the risk of becoming lost.

Three additional classes of hazards are also considered in conjunction with Spirit Mountain Caverns. These classes are not commonly recognized as being associated with cave exploration. The first of these is a risk concerning histoplasmosis, a fungal lung disease. The second risk is associated with exposure to naturally occurring alpha radiation. The third class is exposure to hydrogen sulfide gas.

Commonly recognized cave hazards

Loose and shifting rocks: Spirit Mountain Caverns, like essentially all caves, does contain some loose and shifting rocks. At least a few such rocks can be encountered in all portions of the cave. There are no areas where such rocks are so abundant or so precariously poised as to represent an unusually significant hazard.

Danger of becoming lost: In recognition of this hazard, some people trail string when they visit caves. A much better procedure is to leave removable markers. In Spirit Mountain Caverns, the cave is neither so large nor so complex as to make it likely for someone to become truly lost. Inexperienced visitors might be confused as to the location of the route for perhaps as long as half an hour; we do not view this as a hazard, but instead as a part of the adventure involved in cave exploration. The hazard of becoming lost is not unusually significant in Spirit Mountain Caverns.

Failure of all lights: Most cave rescues result from the loss or failure of lights carried by visitors. In addition, inadequate lighting often results in people becoming lost in caves. Although the hazard is generally perceived by most visitors, people commonly enter caves with lights of inadequate quality and without an adequate supply of spare lights.

Spirit Mountain Caverns is not the sort of cave where one could fumble around in the dark and find his way out with any reasonable degree of safety. There are several places where a person without adequate light could fall a substantial distance. In addition, a fairly thorough exploration of this cave would take typical visitors about six hours; many flashlights will fail within this period. Visitors to Spirit Mountain Caverns should be cautioned specifically and strongly to carry adequate lights of good quality.

Caving literature commonly recommends that people carry three independent sources of light. The shortcoming of this recommendation is that it does not specify the quality of lights.

Better guidance is that each person should carry at least two sources of acceptable light. Candles, chemical light-sticks, matches, lighters, flashlights with undependable switches, flashlights with batteries smaller than size D and gasoline, propane, or kerosine lanterns should not be counted as lights (although some of these items are sometimes nice to

carry). In addition, each flashlight should have new, and preferably long-life type, batteries. Extra new batteries (long-life type) should be carried for at least half of the flashlights in the group.

Carbide lamps (with tip cleaners and spare carbide and water) are significantly more dependable than flashlights. For trips of less than 12 hours, rechargeable Wheat or MSA type battery pack lights are more dependable and provide more light than carbide lamps. Spare parts and repair materials are always prudent.

Lighting requirements should be tempered by the nature of visitation anticipated. For example, a college field trip visiting only the main level of Spirit Mountain Caverns would be well equipted if they had a few Coleman-type lanterns and a flashlight for each person.

Falling down pits: The climbing needed at three points in Spirit Mountain Caverns (Figure 16) justifies some specific warning to visitors. In addition to merely warning the visitor, BLM could advise visitors as to the nature of equipment and techniques needed to safely negotiate these three areas.

The Guano Room Pit is located on the Guano Room Bypass Route between levels 2 and 3 of the cave (Figure 6). The bottom of the pit is in the Guano Room. The pit is about 40 feet deep and is reached from the top through a small crawlway. A belay rope can be safely anchored to a large rock in the crawlway; the use of a rope at least 80 feet long is recommended. People lacking climbing experience may have difficulty negotiating the top of the pit if they climb up this route. This could be alleviated by using a short length of rope or cable ladder, or even climbing slings, at the top of this drop. We found a short length of rope ladder helpful here.

This drop should be belayed even if the visitors are experienced cavers. The most prudent way for the last person to descend this drop is to use a prussic safety or similar technique; the pit would be awkward for a rappel. It is prudent for the first person climbing back up the drop to use a prussic safety. The nature of the climb is such that the rope cannot be retrieved from the bottom of the pit.

The second pit warranting special consideration is the Big Bridge Pit between cave levels 2 and 3 (Figure 16). This pit is about 45 feet deep and consists of two approximately equal segments separated by a ledge. To insure an adequate anchor, at least 100 feet of rope is needed for this drop. Some people would find a rope or cable ladder helpful in negotiating the lower half of this drop.

Even experienced cavers should use a belay in negotiating this drop. Although a rappel could be made here, a prussic safety or similar technique is more reasonable for the last person down the drop. There are some chock stones in the upper half of the drop which could conceivably be loosened by people descending on rappel; a belayed climb is a safer approach.

The Credibility Gap Climb connects levels 1 and 2 of the cave. The climb up from level 2 is the only access route to this portion of level 1. The climb is about 80 feet high with handholds and footholds that are generally good, although there is some loose rock and some holds tend to crumble. The climb is dry. The most difficult part of the climb is the bottom 20 feet.

The first person up the Credibility Gap climb must lead it without any protection. Although the climb is not terribly difficult, it is the

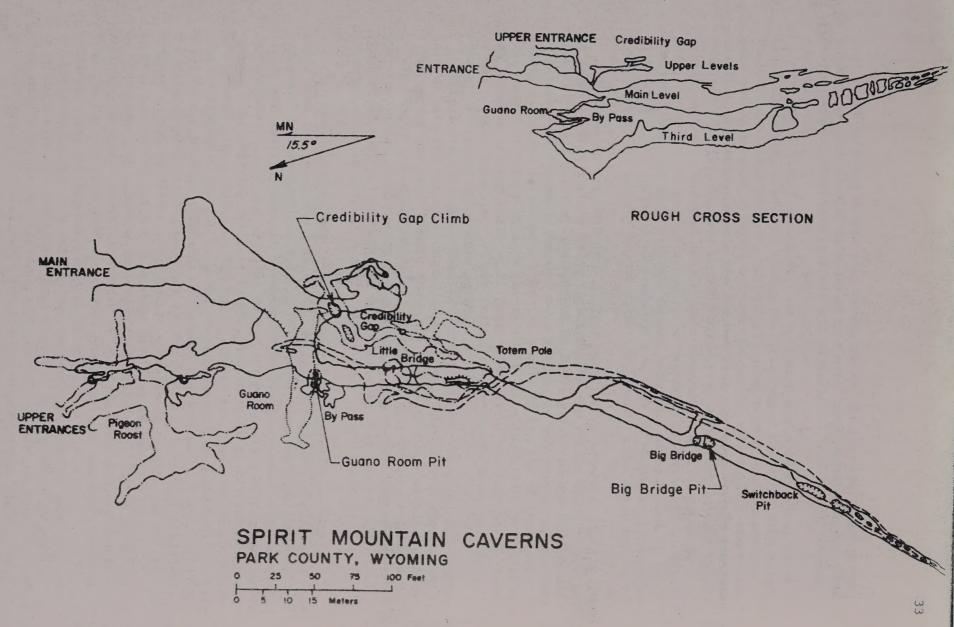


Figure 16. Pits and climbs where the use of technical climbing equipment is recommended.



sort of climb where people will occasionally fall. This climb is long enough that falls could have serious or even tragic consequences. However, the most hazardous part of this climb is not the ascent but the descent.

The Credibility Gap climb goes up and around a bend. Even using disposable slings, we were unable to rig a rappel down this drop which could be retrieved from the bottom. This means that the last person down the climb must climb it without the safety of a belay. The climb is difficult enough to make the descent rather tricky. People regularly involved in mountaineering or vertical caving would probably not have significant problems with this climb. However, the climb could be a risky and treacherous experience for other people. The climb is the sort that once you begin it, the safest course of action seems to be to climb to the top in hopes that you will be able to rappel or find another route down. The reality of the situation is that there is no easy way down.

Because the Credibility Gap climb goes up and around a bend, we found it impossible to throw a belay rope from the top of the climb to the bottom. Since all but the first person up and the last person down should be belayed, at least 175 feet of rope (either in the form of one or two ropes) is needed to get more than two people to the top of the climb. This length of rope permits a person to tie into the middle of the rope and climb to the top while still leaving an end of the rope at the base of the climb. After the climber unties, the rope can be pulled back down again for use by another climber.

People visiting Spirit Mountain Caverns should be cautioned about the two pits and one climb found in the cave. They should also be advised of the equipment needed to safely negotiate these pits and climbs. In the case of the Credibility Gap climb, visitors should be cautioned that this climb should be attempted only by experienced mountaineers or experienced vertical cavers. We do not believe that the climb is so treacherous as to warrant closure of the area to all visitors.

Management recommendations on commonly recognized cave hazards:
Based upon the foregoing discussion, we have developed the following
management recommendations for the commonly recognized cave hazards.

1. People visiting any RLM cave should be cautioned about clippers.

- 1. People visiting any BLM cave should be cautioned about slippery walking surfaces, loose and shifting rocks, the possibility of becoming lost, the need for carrying adequate lights, and the risk of falling off boulders or down pits. Existing BLM "Safety Rules for Little Mountain Caves" (form W-01-6227-5), which is given to people registering to visit Horsethief Cave, provides this sort of general cautioning.
- 2. Hazards associated with loose and shifting rocks in Spirit Mountain Caverns do not represent an unusually significant hazard. We believe a general cautioning (as in recommendation 1) is adequate.
- 3. The hazard of becoming lost is not unusually significant in Spirit Mountain Caverns. Should it occur, it would almost certainly result from the failure of lights carried by the party. We believe a general cautioning (as in recommendation 1) is adequate.
- 4. Visitors to Spirit Mountain Caverns should be advised that the cave is of such size and complexity that lights of good quality as well as spare lights are needed for safe exploration. People planning to explore the cave should carry at least two sources of acceptable light. Candles,

chemical light-sticks, matches, lighters, flashlights with undependable switches, flashlights with batteries smaller than size D, and gasoline, propane, or kerosine lanterns should not be counted as acceptable lights. In addition, each flashlight should have new, and preferably long life type, batteries. Extra new batteries (long life type) should be carried for at least half of the flashlights in the group.

- 5. It is recommended that BLM personnel check parties registering to visit the cave to insure that they have adequate lights. As an alternative, people registering could be asked to certify that they have adequate lights.
- 6. Lighting requirements can be tempered by the nature of the visitation anticipated. People planning to visit only the main level of the cave (level 2) should have at least one acceptable light per person.
- 7. People visiting Spirit Mountain Caverns should be cautioned about the two pits and one climb found in the cave. They could be advised of the equipment needed to safely negotiate these pits and climbs. In the case of the Credibility Gap climb, visitors should be cautioned that this climb should be attempted only by experienced mountaineers or cavers with vertical experience. We do not believe that the climb is so treacherous as to warrant closure of the area to all visitors.

Commonly unrecognized cave hazards

Histoplasmosis and other lung diseases: Histoplasmosis is a lung disease associated with inhaling spores of the fungus Histoplasma capsulatum. Although infection is common (Craigle, 1976), there is generally either no detectable illness or only mild respiratory symptoms. However, there is a progressive type of the disease which is often fatal; this most commonly involves an intense exposure to the spores of Histoplasma capsulatum.

Histoplasmosis is endemic in certain areas of the United States, and in some tropical regions as well. Positive histoplasmin skin tests indicate that 80% of the population in the Mississippi-Missouri-Ohio River Valleys have been affected (Craigle, 1976). In contrast, Histoplasma capsulatum has to date been reported at only one site in Wyoming. The site is Spirit Mountain Caverns.

The Center for Disease Control in Atlanta, Georgia made the determination that Histoplasma capsulatum was present in a sample sent to them. The nature of the sample, as described by Lydy (1979) in a letter to the Cody BLM office was "composed of dirt, feathers, rat pellets, and a variety of unidentified material; really nasty looking stuff". The sample was collected by two BLM cave rangers. Although no information on the precise location from which the sample was collected was found in the BLM files, the presence of feathers in the sample indicates that it was collected either in the Pigeon Roost area or on the route to that area. This was confirmed by Pete Uhl, one of the BLM cave rangers who collected the sample.

Spores of <u>Histoplasma capsulatum</u> have been found only in association with bird droppings and bat guano. Based upon a discussion in 1979 with Dr. Robert W. Lichtwardt, a mycologist at the University of Kansas involved in research on this fungus, spores of <u>Histoplasma capsulatum</u> have never been found associated with droppings from packrats. The explanation for this may be related to differences in the digestive systems and digestive enzymes between bats and birds and other vertebrate animals.

Regardless of the explanation, the restriction of spores of Histoplasma capsulatum to bird droppings and bat guano has cave management significance in Wyoming. Our concern about histoplasmosis can be restricted to areas of caves which contain bat guano or bird droppings.

We saw no bats in Spirit Mountain Caverns; cave dwelling bats are generally rare in Wyoming caves. Packrat droppings are scattered through out the cave. Large bird populations are uncommonly associated with caves, but Spirit Mountain Caverns, with its large pigeon population, is a notable exception. Pigeon use of the cave is restricted to the Pigeon Roost area, although some of the pigeon droppings and feathers have migrated into some of the small passages on the route between the main level of the cave and the Pigeon Roost area. Packrats have probably helped spread this material around.

During our field work we collected nine samples of soil and fecal material from Spirit Mountain Caverns for subsequent analysis for the presence of spores of Histoplasma capsulatum. The samples were collected in sterile bags using sterile spoons. The samples were given to Mr. Wayne Holm at the BLM office in Cody; he will ship them to the Center for Disease Control in Atlanta, Georgia where analysis work will be done.

Table 1 summarizes data on the location of the nine soil and fecal sample collection sites in Spirit Mountain Caverns; the locations are shown on the map in Figure 17. Table 1 also indicates whether the collection site was a location where cavers were likely to travel and thus be exposed. Some of the samples were collected from packrat debris in small alcoves where people would not travel.

The analysis of samples for Histoplasma capsulatum (as conducted by the Center for Disease Control) takes several weeks. As a result, we have not yet received the results. Once the results are received, we will analyze them in an addendum for any impacts they may have on cave management. BLM personnel will add this addendum (Addendum 1) to all of their copies of the report. However, based upon our present knowledge of the natural history of this fungus and the nature of the cave, we believe we can develop prudent management recommendations for relating to this hazard without waiting for the final results from CDC. Any changes in our conclusions and recommendations will be incorporated in Addendum 1.

Although histoplasmosis is a newly discovered issue affecting cave management in Wyoming, it is not a new issue in other parts of the United States. Management approaches used by other state and federal agencies in areas where histoplasmosis commonly occurs can give some guidance to BLM in dealing with the issue in Wyoming.

The BLM files in Cody contain some very helpful correspondence between Thomas Enright and Warren C. Lewis, M.D. on the subject of histoplasmosis (Appendix B). Dr. Lewis states that Histoplasma capsulatum spores have been found in several caves open to the public, including Carlsbad Caverns in New Mexico (administered by the National Park Service). Spores of Histoplasma capsulatum could probably be isolated from Mammoth Cave, Kentucky (administered by the National Park Service), Blanchard Springs Caverns in Arkansas (administered by the U.S. Forest Service), as well as many other public and private caves. At these caves, visitors are not warned of any special hazards. Employees or visitors working or exploring where they could stir up spores are typically cautioned about the disease. We believe this to be a proper course of action.

Table 1

Location and related data on soil and fecal samples collected in Spirit Mountain Caverns for <u>Histoplasma capsulatum</u> analysis.

Sample #	Cave Level	Location	Caver Exposure Likely?
W-1	1	Top of Credibility Gap; packrat debris.	No
W-2	1	Top of Credibility Gap; typical cave dirt	Yes
W-3	between 2 & 3	Guano Room Bypass route; crawl immediatel above Guano Room Pit. Typical cave dirt.	
W-4	3	Lower end of main linear passage.	Possibly
W-5	4	Main route in lowest level of the cave; typical cave dirt.	Yes
W-6	2 on route to 1	Halfway between main passage and Pigeon Roost Area. Vicinity of previous positive histo sample. Cave dirt, packrat dropping pigeon feathers and droppings.	
W-7	2	Packrat debris in alcove along the main passage 80 feet from gate.	No
W-8	2	Main passage at the intersection with the route to the Pigeon Roost area. Typical cave dirt.	Yes
W-9		This sample collected at Horsethief Cave	
W-10	between 2 & 3	Guano Room Bypass route; breakdown chambe above Guano Room Pit. Typical cave dirt.	

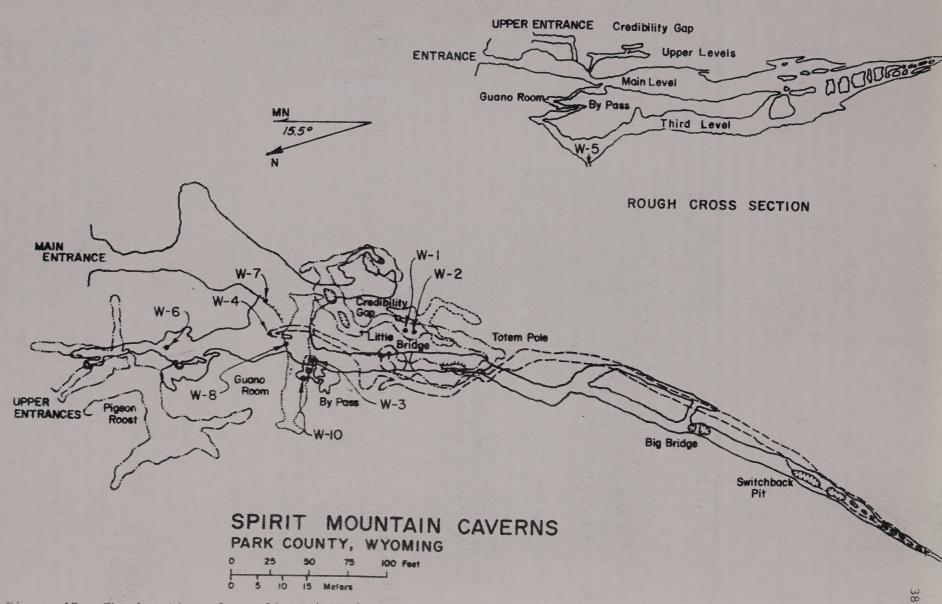


Figure 17. The location of sampling sites for the fungus Histoplasma capsulatum.



As mentioned earlier, the severity of the disease tends to be associated with the intensity of the exposure. Fatal cases of histoplasmosis have resulted in Missouri among workmen who were bulldozing out trees and leveling the ground in areas which supported giant starling roosts; nearby residents were not affected. With cavers, cases of histoplasmosis serious enough to involve medical treatment have typically resulted from horseplay in piles of bat guano and/or nearby cave dirt. In addition, a number of cavers who have visited caves in central America or the Caribbean have also suffered bouts with histoplasmosis. Many of these tropical caves contain hundreds of thousands and even millions of bats; cave exploration involves substantial contact with bat guano. Prudent cavers who have a concern for the well-being of their lungs do not romp through the guano nor frolic in dust contaminated with bat or bird feces.

Based upon our understanding of histoplasmosis, the risk of potentially contacting a detectable case of this disease is negligable in most portions of Spirit Mountain Caverns. The hazard exists only where there is a substrate of pigeon droppings; these conditions are found only in the Pigeon Roost area and in immediately adjacent areas.

People traveling toward the Pigeon Roost area from level 2 of the cave must pass through some steeply inclined crawlways where it is impossible not to stir up dust. As one nears the Pigeon Roost area, this dust becomes obviously contaminated with pigeon droppings and feathers. In order to make it all the way to the Pigeon Roost area, it is now necessary to partially excavate a connecting crawlway; the crawl is primarily plugged with pigeon droppings. The fact that we did not excavate this passage and continue on to the Pigeon Roost area is indicative of the seriousness with which we view this hazard. Similarly, we did not descend into the Pigeon Roost area from outside the cave; we did not view this as prudent either.

Histoplasmosis is not the only disease which can be associated with bird droppings. Several years ago one of the authors of this report had a serious case of parrot fever and pnemonia which lasted for several weeks. This was a result of cleaning out a Missouri turkey house which had been unused for several years. Possibly this or similar diseases could result from travel into those portions of Spirit Mountain Caverns which are heavily used by the pigeons.

Management recommendations on histoplasmosis: With respect to the hazards of histoplasmosis and other bird-related diseases, the following cave management actions are recommended.

- 1. The risk to visitors does not warrant the closure of the cave or general restriction of access. Many people have visited the cave in the last few years, yet to our knowledge there have been no reports of cases of histoplasmosis which might have been related to visitation of this cave.
- 2. All visitors to the cave should be cautioned that the fungus Histoplasma capsulatum has been isolated from a sample containing pigeon feathers and feces, packrat droppings, and cave dust. Although the pigeon feces are almost certainly the only medium which will support the spores of this fungus, it is prudent not to stir up any dirt or fecal material found in the cave. An adequate gate and a permit system for the cave would insure that all visitors were cautioned about this hazard.

- 3. Visitors should be warned that the Pigeon Roost area and the route to this area are considered to be hazardous because of the fungus Histoplasma capsulatum and the abundance of pigeon feces, which provide a good substrate for this fungus.
- 4. A sign should be placed on the route to the Pigeon Roost area informing visitors that this is the area of the cave where the hazard of histoplasmosis is believed to be significant. The sign should be placed at the entrance to the first crawlway after leaving the main cave passage on the route to the Pigeon Roost area. The sign should strongly recommend that people not proceed further. The sign might also state that the passages beyond are small and not of particular interest.
- 5. Spores of the fungus <u>Histoplasma capsulatum</u> can persist in soils for many years. Exclusion of pigeons from the cave would not solve the problem. Soil sterilants do not effectively kill spores of <u>Histoplasma capsulatum</u>. Histoplasmosis is a long term and uncorrectable situation which will always require at least some management attention.

Naturally occurring alpha radiation: A detailed discussion of the cave radiation issue (which includes an assessment of the risk, recommendations for management action, and existing National Caves Association precautionary health standards for alpha radiation exposure in caves) is found in Appendix C. The information in Appendix C may be read prior to reading the detailed information included below on Spirit Mountain Caverns.

Alpha radiation concentrations were measured at 12 stations in Spirit Mountain Caverns. These data were collected in conformance with contract specifications. Radon daughter concentrations measured on August 19, 1979 at stations 10, 11, and 12 were lower than anticipated (Table 2, Figure 18). Therefore, on September 7, 1979, samples were again collected at these three stations. It is our conclusion that radon daughter values collected on August 19 for stations 11 and 12 were in error, probably due to erratic behavior experienced with the equipment. Thoron daughter values for these samples were correct. Both of the radon daughter samples collected at station 10 were correct.

During the radiation sampling periods in Spirit Mountain Caverns, air flow was generally moving into and descending through the cave. The explanation for this direction of flow is that outside air temperatures were warmer than cave temperatures. For example, on August 19, 1979 at llam the surface air temperature was 56 degrees. It had been sprinkling rain since 2pm on the previous day, and surface temperatures had been fairly stable.

There are probably many very small openings from the surface into Spirit Mountain Caverns. This is indicated by airflow patterns, but is also indicated by the packrat piles distributed throughout the cave. Riskind and Van Devender (1979) state that packrats rarely venture more than 300 feet from the protection of their houses. Since packrat materials are found essentially throughout Spirit Mountain Caverns, we believe that most of the cave lies within 300 feet of a surface opening accessible to packrats.

When outside air is warmer than cave air (and when a cave has more than one entrance through which air can move), cold cave air sinks out of the cave through the lowest entrance because the cave air is denser than the warmer surface air. Replacement air is then sucked into the upper entrance of the cave. This flow pattern explains why we recorded such

Table 2

Results of 1979 alpha radiation monitoring in Spirit Mountain Caverns. Radiation values are in working levels, temperature in degrees F.

Station & Location	Cave Level	Date	Time		Thoron dgts.	Total	Temp.
1 Top of Credibility Gap	1	8/18	1:13*	*4.30	0.01	4.31	47
2 Entrance gate	2	8/19	9:11	0.59	0.003	0.59	47.5
3 Main pass. 90 ft. from gate	2	8/19	9:24	0.25	0.01	0.26	43.5
4 Under Little Bridge	2	8/19	9:34	0.82	0.002	0.82	44
5 Top of steps nr. Big Bridge	2	8/19	11:06	0.96	0.003	0.96	45
6 50 ft. past station 5	2	8/19	11:19	1.02	0.003	1.02	45
7 Rm. above Guano Rm. climb	2-3	8/19	11:52	0.99	0.000	0.99	43
8 Bottom level, 100 ft. from base of Guano Rm. Bypass	4	8/19	4:17*	*0.58	0.01	0.59	44
9 Base of Guano Rm. Bypass	3	8/19	4:28*	*0.65	0.03	0.68	45
10 Halfway to Pigeon Roost	2-1	8/19	5:20*	*0.11	0.005	0.11	47
10 Halfway to Pigeon Roost	2-1	9/7	2:59*	*0.004	n.m.	n.m.	n.m.
11 End of tourist route pit	3	8/19	4:40*	*d.d.	0.02	n.m.	46
11 End of tourist route pit	3	9/7	3:13*	*0.66	n.m.	n.m.	n.m.
11 Composite for station	3	8/19&9	77	0.66	0.02	0.68	46
12 Base of Big Bridge Pit	3	8/19	4:49*	*d.d.	0.02	n.m.	46.5
12 Base of Big Bridge Pit	3	9/7	3:21*	*0.57	n.m.	n.m.	n.m.
12 Composite for station	3	8/19&9	7/7	0.57	0.02	0.59	46.5
Mean	****	***	w.	0.96*	0.01	0.97	45

Abbreviations: n.m.=not measured, d.d.=data dropped; believed to be in error (see text), dgts.=daughters

^{*} Excludes station 10 on 9/7.

^{**}these times are pm, all other times are am

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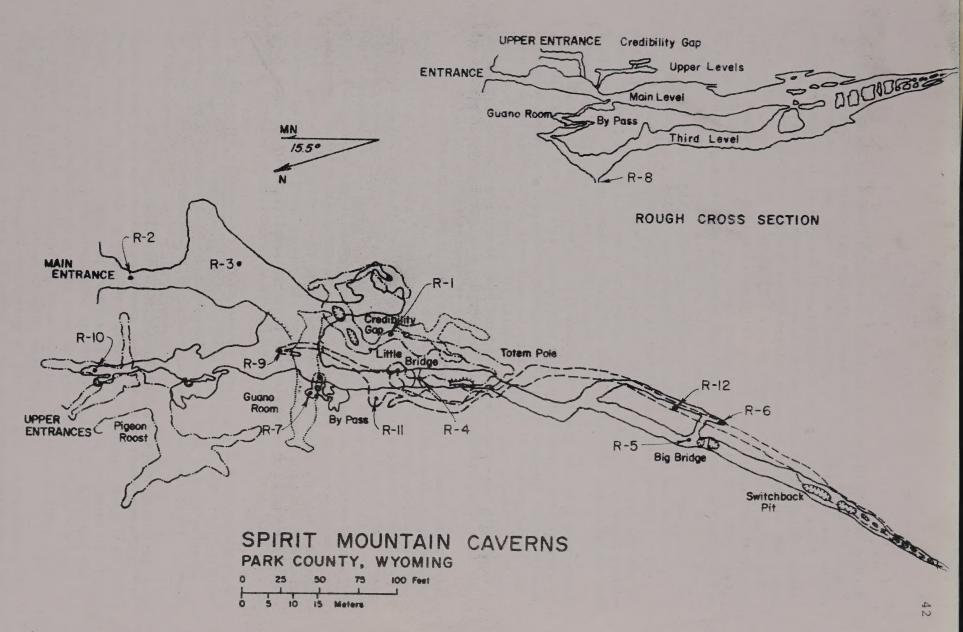


Figure 18. The location of alpha radiation monitoring stations.

low radon daughter concentrations at sampling station 10 (which is half-way between the main passage and the Pigeon Roost area). Alpha radiation at station 10 was lower than at station 2 (the entrance gate to the cave) because station 2 is not the uppermost entrance to the cave.

The highest alpha radiation concentration measured in Spirit Mountain Caverns (and the highest concentration measured in any of the caves monitored) was at station 1 (at the top of Credibility Gap). When measured on August 18, 1979, airflow in this area was slight; the direction of the flow was into the cave. This probably indicates that there are few (if any) upper airflow entrances connecting from the surface to this portion of the cave. As a result, air circulation is slow, and alpha radiation concentrations are higher than in other parts of the cave.

On August 16, 1978, radon daughter alpha radiation was measured between 1 and 1:30 pm at two points in Spirit Mountain Caverns. This monitoring was done by BLM cave rangers. At a point near our station 3, alpha radiation was 1.35 working levels. At our station 5, alpha radiation was 1.95 working levels. No other alpha radiation measurements have apparently ever been taken in this cave.

Alpha radiation concentrations measured in 1978 and 1979 were somewhat different, but this is normal. At most caves where measurements have been made, one can detect moderate daily and seasonal fluctuations. Measurements made at the same time of year (but on different years) can also show a moderate amount of variation. This is particularly true in the case of measurements made near cave entrances where the effects of air exchange between the cave and the surface are pronounced. Most of Spirit Mountain Caverns is near entrances.

The concentrations of alpha radiation which we measured in Spirit Mountain Caverns are within the range commonly encountered in wild caves of medium to large size. The concentrations we encountered are similar to those usually encountered during the summer along tourist routes in Mammoth Cave, Kentucky. The values are also similar to those which have been measured in the summer in medium to large sized caves in the Ozarks of Missouri and Arkansas. Some large cave systems in Kentucky have alpha radiation concentrations several times larger than those measured in Spirit Mountain Caverns. The purpose of this comparison is to let land managers know that these values are neither unusually high nor unusually low. Based upon our monitoring, there do not appear to be any unique radiation hazards associated with Spirit Mountain Caverns.

Management recommendations on alpha radiation: Based upon radiation monitoring and an appraisal of the hazards involved in cave radiation exposure, the following management recommendations have been developed.

1. Alpha radiation should not be considered a significant health hazard at this cave.

2. Based upon alpha radiation concentrations measured in Spirit Mountain Caverns and the fact that most visitation will be of short duration, it isn't necessary for BLM to caution visitors to this cave about cave radiation. The average visitor probably will spend about two hours in this cave. Based upon our measurements, the total amount of alpha radiation a visitor would receive from this cave is approximately equal to that received from spending four days in a building. In our opinion, this does not justify warning or cautioning visitors.

3. If additional radiation monitoring is done in this cave, sample station one should be deleted. Although it has the highest concentration

measured, it is in an area where most people do not go. More importantly, however, it is difficult and dangerous to reach this station, and any values obtained do not justify the risk of a possible fall on the climb into this area.

- 4. If personnel and funds are available, stations 2 through 12 should be monitored for alpha radiation during the summer of 1980 to develop baseline data.
- 5. If it appears that the cave will receive appreciable non-summer visitation, it would be good to monitor stations 2 through 12 once during this period. It is anticipated that the resulting values would be lower than those collected during summer, 1979 monitoring.

Hazards of hydrogen sulfide gas: Claud Brown, who formerly operated Spirit Mountain Caverns, reported to the Bureau of Land Management that hydrogen sulfide gas could be smelled in the cave. He reported that because of the smell of the gas, passages were blocked so that the gas would be kept from the tourist route. As a result of this report, one task of this contract was to monitor the cave for hydrogen sulfide gas.

There are two precesses which can account for significant quantities of hydrogen sulfide gas in cave air. Hydrogen sulfide can be liberated by decaying organic material; this periodically occurs in caves in humid areas, but is not likely in the Spirit Mountain Caverns area. Secondly, geothermal activity can result in hydrogen sulfide gas in cave air. Since sulfur vents are present in the base of Cedar Mountain (on which Spirit Mountain Caverns is located), this is the probable source in this cave if significant quantities of this gas are present.

Hydrogen sulfide has an odor threshold of 0.02 parts per million (ppm) (Safety International, Inc.; undated). During our work in the cave we did not smell any hydrogen sulfide. Since the detection threshold for the monitoring equipment we had available was above 0.02 ppm, and since the monitoring equipment had operating problems, we did not monitor for the presence of this gas.

Table 3, developed from data in Safety International, Inc (undated), National Safety Council (undated), and NIOSH (1977) may help in the appraisal of the hazards of hydrogen sulfide gas.

Hydrogen sulfide gas has a specific gravity of 1.189. It is thus heavier than air and tends to be concentrated in low places. This does not mean, however, that moderate concentrations of this gas might not be found in cave air. The following quote from Egemeier (1973) should be of particular interest in this regard, particularly since some of these caves may be on BLM administered lands:

"The air in the active caves (Lower Kane and Hellespont Caves) contains hydrogen sulfide gas. The odor is strongest in Hellespont Cave; in fact, exposure to the air in this cave produces mild nausea and headache in a few hours. The highest gas concentration in Hellespont Cave appears to be at the far end near the spring. The gas odor in Lower Kane Cave is strongest near the Upper and Lower Springs. One experiences mild nausea and headache after approximately eight hours exposure to Lower Kane cave air. The high gas concentrations near the springs suggest that the gas is coming from the springs...As far as can be determined these Wyoming caves are the only reported air-filled caves containing an appreciable quantity of hydrogen sulfide".

Table 3

Physical effects of varying concentrations of hydrogen sulfide gas. Data from Safety International, Inc. (undated), National Safety Council (undated), and NIOSH (1977).

Concentration (ppm)	Physical effects
0.02	Odor threshold
10.00	Obvious and unpleasant odor (rotten egg odor)
20.00	Safe for 8 hours of exposure
50.00	Peak concentration allowed by OSHA without respirator
100.00	Kills smell in 3 to 15 minutes; may sting eyes and throat
200.00	Kills smell shortly; stings eyes and throat
500.00	Dizziness; breathing ceases in a few minutes. Needs prompt artificial respiration
700.00	Unconscious quickly; death will result if not rescued promptly
1000.00	Unconscious at once, followed by death within minutes

Based upon data in Table 3 and information in Safety International, Inc. (undated), it seems likely that the hydrogen sulfide concentrations which Egemeier (1973) encountered probably were higher at times than those he measured. Egemeier (1973) measured a few hydrogen sulfide gas concentrations; his largest value was 11 ppm. If our conclusions on concentrations are correct, these are risky concentrations to encounter.

Although we did not detect any hydrogen sulfide gas in Spirit Mountain Caverns during our field work, this does not necessarily prove that it never exists in the cave. Our work was in the summer when outside air temperatures were warmer than cave temperatures, and as a result airflow in the cave was downward. If hydrogen sulfide occurs in the cave and is derived from deep sources, the summer airflow pattern in Spirit Mountain Caverns would tend to keep hydrogen sulfide gas from intruding into the accessible parts of the cave system.

Under cold weather conditions, the direction of airflow in the cave would be reversed. With these conditions, hydrogen sulfide gas might be encountered within Spirit Mountain Caverns.

When hydrogen sulfide gas encounters oxygen dissolved in water, it forms sulfuric acid. Sulfuric acid corrodes metals (this is what happens in a flashlight when a battery leaks). In addition, hydrogen sulfide gas is very corrosive, and blisters and pits metal. Because of the effects on metals, a nail which had been in level 3 of the cave since construction activities in the 1950's was carefully examined. There was no evidence of any hydrogen sulfide or sulfuric acid corrosion on the nail. Similarly, beer cans and other metal trash in the cave (levels 2, 3, and 4) did not show any evidence of corrosion. Based upon this evidence, hydrogen sulfide gas is probably absent or present in only very low concentrations within Spirit Mountain Caverns at the present time.

As discussed earlier, the formation of the gypsum crust in Spirit Mountain Caverns is attributed to reactions involving hydrogen sulfide gas. If hydrogen sulfide gas has been present in the cave in the past, it may on occasion still be present, or it may again be present at some time in the future.

One other factor which should be considered is the fact that there can be some odors in the cave derived from the pigeon use of the Pigeon Roost area. It is possible that this is the source of odors, rather than hydrogen sulfide. Pigeon feces emit the odor of ammonia rather than hydrogen sulfide, yet it is possible that the difference was not distinguished by people reporting odors in the cave.

Management conclusions and recommendations on hydrogen sulfide gas hazards:

- 1. Hydrogen sulfide gas was not detected during our work. Furthermore, pieces of metal found in the cave showed no corrosion which could be attributed to either hydrogen sulfide or sulfuric acid. As a result, we do not believe that hydrogen sulfide gas represents a major safety hazard in this cave.
- 2. If hydrogen sulfide gas is present in Spirit Mountain Caverns, it would most likely be detected during cold weather conditions. People visiting the cave during cool or cold seasons of the year should be asked if they noted any of the "rotten egg smell" of hydrogen sulfide gas while they were in the cave.

- 3. As a precaution, until reports are received on the presence or absence of hydrogen sulfide gas in the cave during cool or cold seasons, cave visitors should be cautioned that hydrogen sulfide has been reported in the cave, and may occur during the cool and cold seasons of the year.
- 4. Cave visitors should be particularly cautious if they smell any hydrogen sulfide. Under these conditions, people should be wary of entering low spots in the cave, since the gas could accumulate in such places. They should leave the cave if they encounter an obvious and unpleasant odor of hydrogen sulfide. Visitors should be cautioned that dangerous concentrations of hydrogen sulfide gas quickly kill the sense of smell, and concentrations of one part of hydrogen sulfide gas in 1,000 parts of air will cause a person to become almost instantly unconscious. Various symptoms, including eye irritation, headache, dizziness, nausea, coughing, excitement, drowsiness, and dryness and sensation of pain in nose, throat and chest are associated with different concentrations of hydrogen sulfide gas.

Cave rescue

An evaluation of cave rescue problems in Spirit Mountain Caverns was not required under this contract. However, a short discussion of this issue would be helpful to the management of this cave.

Search activities will most likely result from people entering the cave with insufficient or inadequate lights. If injuries serious enough to require rescue should occur, they will probably occur at the pits and climbs shown in Figure 16. Rescue with litters would be very simple from the base of the Credibility Gap climb. With a few flash-lights, the local ambulance crew could handle such a rescue.

A rescue from the base of Big Bridge Pit (or nearby Switchback Pit) could be done with a litter, but would require people experienced in mountain rescue (or cave rescue) work. As cave rescues go, it would be a very simple one for an adequately trained and equipted rescue team.

An injury in the Guano Room Pit area serious enough to require rescue would be more difficult. Because of a tight spot at the top of the Guano Room Pit, and the small connection crawlways, the best route for removing the injured person from the cave would be to descend into level 3 of the cave and then raise the person through Big Bridge Pit. Such a rescue would require an experienced and adequately equipted rescue group which hopefully had some cave experience.

NATURE AND EXTENT OF PAST CAVE INTRUSIONS

Spirit Mountain Caverns was developed as a show-cave in 1955, and was open to the public from about 1955 to 1966. The tour route led from the main entrance along level 2 of the cave to Switchback Pit (Figure 5). Wooden steps and platforms were built above Big Bridge Pit, and steps descended through Switchback Pit into level 3 of the cave.

The tour route on level 3 ran from the bottom of the stairs below Switchback Pit to a point labelled "End of Tourist Route Pit" on Figure 7. The total length of developed trail in the cave was 800 feet.

During the commercial development of the cave, a front end loader was used along level 2 of the cave. The main entrance to the cave was at one time a high fissure, but during commercial development, it was modified to a classic arch type entrance (Hill et al., 1976). This allowed the front end loader to enter the cave. Work with the front end loader was apparently restricted to the first 120 feet of the cave. Most of this work consisted of lowering the natural floor level by removing dirt and breakdown blocks. The material which was removed was taken outside and dumped from the cave into the canyon below. Work with the front end loader apparently ended when it fell into the canyon and the man operating it was killed. The front end loader also reportedly fell into a pit in the cave; we could find no evidence of a pit where this could have occurred, but it could have been filled during construction. On the other hand, this story may be legend.

Beyond the area where the front end loader was used, hand work was done to level the floor along the tour route. During this construction, the diameter of the Log Pit (which is the entrance to the Guano Room Bypass route) was substantially reduced. Large logs were placed across part of the pit. On top of these, smaller logs were placed at right angles; rock and dirt were placed on top of the smaller logs. The trail ran across the top of this pile. Figure 19 is a photograph of the trail over the Log Pit; the post in the photo protrudes from the remaining portion of the Log Pit.

At Big Bridge and Switchback Pits there is a substantial amount of lumber which was used for steps and platforms. Figure 20 is a photograph of the platform and stairs at Big Bridge Pit. There are no handrails remaining on any of the steps or platforms. Note that some steps are missing and that some boards are broken on the platform.

Cave development activity on the third level made only minor changes in the appearance of the cave passage. The cave floor was somewhat Leveled, and trails were made of dirt and rock. The nature of the trail can be seen in Figures 14 and 15. We do not consider the trail on the third level to represent a significant intrusion.

The lighting system used when the cave was open to the public has all been removed. The most noticeable evidence of past development of the cave is the wooden remains of platforms and steps. Table 4 tabulates the location, nature, and amount of this material.

Since its discovery, the cave has suffered substantial vandalism. The most serious vandalism has been the removal of gypsum crustmand other cave formations from the cave. This has been most severe on the easily accessible portions of level 2 of the cave, but has occurred throughout the cave system. It seems likely that much of this vandalism has occurred since 1966 when the commercial venture failed.



Figure 19. The Log Pit, which is the entrance to the Guano Room Bypass route.

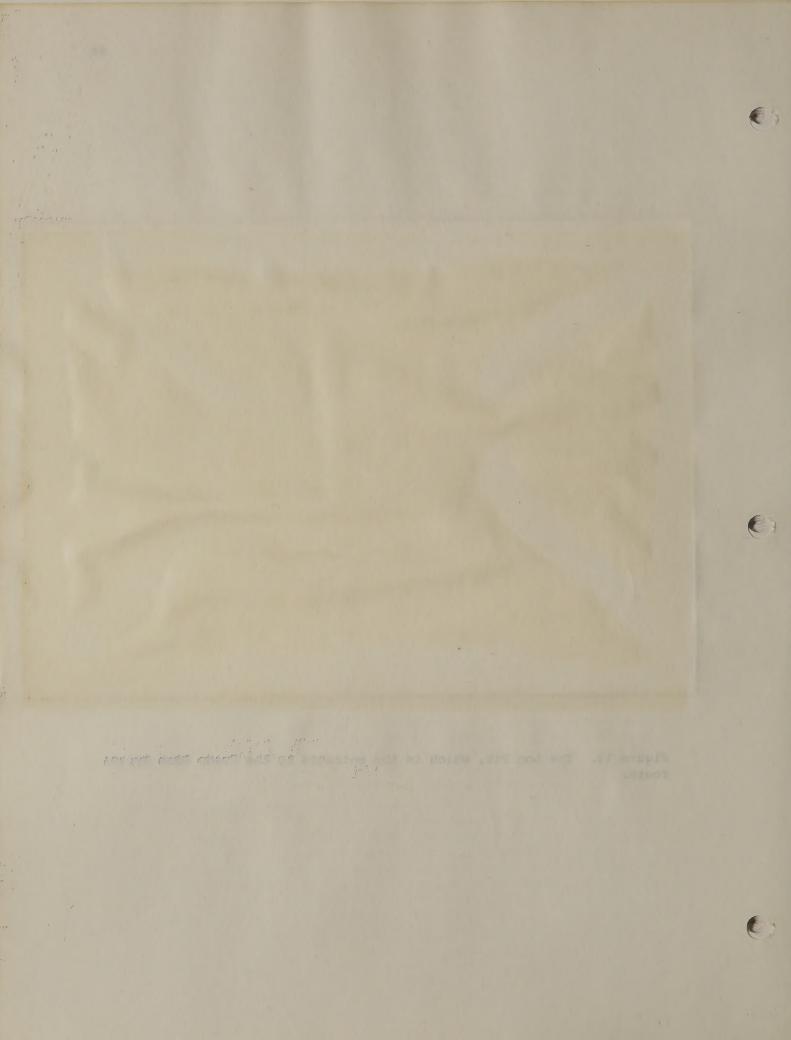




Figure 20. The platform and stairs at Big Bridge Pit. Note that some of the boards are missing and that some steps are broken.

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Table 4

Location, nature, and amount of debris and trash in Spirit Mountain Caverns.

Location	Nature of Debris	Amount
Level 2, base of Cred- ibility Gap*	Lumber	50 board feet of 2 X 12
Level 2, 30 ft. from entrance*	Lumber in steps	145 board ft. of 2 x 12,
Entrance*	Lumber in steps	145 board ft. of 2 x 12
Entrance*	Pipe	50 ft.,3 inch diameter
Entrance*	Cable & anchor	15 ft., inch diameter
Level 2, Log Pit	Poles and logs, 4 to 10 in. dia.	200 to 300 linear feet. Removal not recommended
Level 2, Big Bridge Pit	Lumber in steps and platforms	390 board feet of 2 X 12 and 2 X 6. Some disassembly and cutting required.
Level 2, Big Bridge Pit	Poles in plat- forms and steps	82 linear feet of 4 in. dia- meter poles in lengths 8 to 14 feet long
Level 2, Big Bridge Pit	Steel cable	75 ft., ½ in. diameter
Level 3, Switchback & Big Bridge Pits	Lumber	245 board ft. of 2 X 12, 2 X 8, and 2 X 4.
Level 3, Switchback & Big Bridge Pits	Poles	50 ft. of 4 in. idameter
Level 3, Switchback & Big Bridge Pits	Woven wire	50 ft. of 3 ft. high galvan- ized fencing
Level 3, end tourist route pit	Lumber	90 board ft. of 2 X 12 and 2 X 4
Level 3, end of tourist route pit	Pole	16 ft. of 4 in. diameter
All levels except level 1	Cans, bottles, & broken glass, and other debris	10 - 30 gallon trash sacks full

Summary:

Lumber: 1,065 b.f. (340 b.f. removed August, 1979 by BLM)
Poles (excluding Log Pit area): 148 linear ft. of 4 in. diameter
Other construction materials: 50 ft. woven wire, 75 ft. of ½ in.
cable

Glass, cans, paper: 10 - 30 gallon trash sacks full

^{*}Materials removed by BLM in August, 1979

There are some names, arrows, and other markings on walls of the cave. These are found throughout levels 2, 3, and 4. Figure 21 shows spray paint defacement along the main passage on level 2 beneath Little Bridge. Although there is a moderate amount of defacement in the cave, most of it could be removed or concealed. Soot from carbide lamps can be washed away. Spray paint is difficult to remove; it often requires that the surface be abraded away or else that mud be smeared on the wall to obscure the marks. In the case of spray paint on the gypsum crust, scrubbing with vinegar and a brush might effectively remove the markings.

Beneath Big Bridge and lower than the present trail platform there is a "signature rock" with many names and dates from the early 1920's. These were the oldest dates we noted in the cave, even though discovery occurred in 1908. We see no reason for preserving these signatures. Perhaps signatures from 1908 or 1909 should be preserved; however, dates of this period were not found. Since the Worland District has a staff archeologist, he could be consulted about removing names from the signature rock before this action is taken.

Management recommendations for cave clean-up

Past activities in Spirit Mountain Caverns have had substantial impacts on the natural features and natural integrity of the cave system. Some of these impacts (for example, the breakage and removal of cave formations) cannot be repaired. Other impacts, however, can be partially to largely offset. Actions which remove or mitigate past impacts will increase the value of cave resources within Spirit Mountain Caverns. The following management actions are recommended.

- 1. Lumber and most other materials remaining in the cave from the time when the cave was used as a show-cave should be removed. This clean-up will not only improve the natural appearance of the cave, but will also make visitation safer. At present, some of this debris is a safety hazard. Figure 20 provides a good illustration of this; note the broken boards and missing steps where people could be injured. In other places, nails protruding from old boards are a distinct hazard. Finally, some people are using the boards, cables, and old fence pieces to descend or cross pits; this is a very unsafe practice which would end if these materials were removed from the cave.
- 2. The Log Pit area presents a special case. The logs in this area should not be removed. Removal of the logs would require substantial rock moving, and some of the rocks are quite large and the job would be difficult. Removing the logs probably would be more disruptive to the cave than leaving them in place. Eventually, the logs will decay and the area will subside somewhat; this probably will not plug the Guano Room Bypass route. At present, the logs appear sound, and collapse in the area is not likely.
- 3. Cans, bottles, and other trash should be removed from the cave. At present, there is a substantial amount of broken glass. Some of this glass is in places where it could cut people. We estimate that there are about ten thirty gallon trash sacks full of trash in the cave.
- 4. The names, arrows, and other markings on the walls of the cave should be removed. Those made with paint may need to be obscured rather than removed.



Figure 21. Spray paint defacement of the cave wall beneath Little Bridge along the main passage in level 2.

- 5. An archeologist could determine if signatures on the "signature rock" near Big Bridge should be removed or not. If signatures from 1908 or 1909 are found they should be brought to the attention of a BLM archeologist as they may be of historical significance (the cave was discovered in November, 1908).
- 6. Visitors should be specifically told not to litter or deface the cave, and they specifically should be cautioned not to break or remove any natural materials in the cave.

Time estimates for work planning: Recommendation 1 would require 3 days of work by a three man crew. This effort would remove all materials to a point outside of the cave. We have not estimated the time necessary to take this material from the cave entrance to a proper disposal site.

Recommendation 2 does not require any work in the cave.

Recommendation 3 would require two days of work by a three man crew. Since there is a substantial amount of broken glass, plastic bags would not be suitable for most of the collection effort.

Recommendation 4 would require about one day of work by a three man crew.

Recommendation 5 would not require any work in the cave. Recommendation 6 would not require any work in the cave.

CAVE MANAGEMENT AT SPIRIT MOUNTAIN CAVERNS

Spirit Mountain Caverns was discovered by Ned Frost in November, 1908, and was initially known as Frost Cave. On September 21, 1909, President William A. Taft proclaimed,

"A cavern in the state of Wyoming, of unknown extent but of many windings and ramifications and containing chambers of large size, magnificently decorated with sparkling crystals and beautiful stalactites, containing impenetrable pits of unknown depths is of great scientific interest and value to the people of the United States".

From 1909 until 1954, the cave was the focal point of Shoshone Caverns National Monument under the administration of the National Park Service. In 1954 it was eliminated from the National Park system and was patented by the City of Cody for recreational use under the Recreation and Public Purposes Act. From about 1955 to 1966 the cave was open to the public as a show-cave, having been developed by Mr. Claude Brown under a lease arrangement with the City of Cody. After the failure of the show-cave venture, the cave received little management or protection until December, 1977, when the caverns reverted to BLM administration.

The reason the management history of Spirit Mountain Caverns is cited is to make an important point about cave management and this cave. For over 70 years people have been trying to develop a workable scheme for protecting and using this cave. To date, none of the approaches which have been tried proved to be suitable for this cave. The development of a workable management scheme for this cave, one which will insure both the protection of the cave and will also permit use and enjoyment of the resource, presents a most intriguing challenge.

General cave management conclusions and recommendations

- 1. Spirit Mountain Caverns is of both state and regional significance. It is a cave worthy of protection and management. Furthermore, it is a cave with substantial educational and recreational value.
- 2. In the past, the cave has suffered serious vandalism. In addition, the cave contains a substantial amount of trash and debris, some of which remains from the former commercial activities in the cave. Although the cave cannot be restored to its pristine condition, dramatic improvements can be made over present conditions. Recommendations for these improvements are listed in the section entitled "Recommendations for cave clean-up".
- 3. Adequate protection of the cave will require that access to the cave be controlled. The present gate could be improved and strengthened so that people cannot enter the cave without permission.
- 4. A check-out procedure similar to that used for Horsethief Cave should be instituted for Spirit Mountain Caverns. We were very impressed with how well this system appears to be protecting the cave resources at Horsethief Cave, and hope that it would be equally effective in protecting natural values in Spirit Mountain Caverns. Furthermore, a check-out procedure allows BLM personnel to caution visitors about health and safety hazards, and to determine if parties visiting the cave have adequate equipment.

- 5. In the past, Spirit Mountain Caverns has been the site of many "beer parties"; cans and bottles are found throughout the cave. This use is totally inappropriate for this cave, and causes damage to resources and significant visitor safety problems. A way of discouraging this type of use would be to permanently close the road to the cave at the point where it leaves the main dirt road leading to the top of Cedar Mountain. From this point it is an easy 10 minute walk to the cave; such a road closure would not adversely affect proper use of the cave. This road could be closed in such a way as to prevent access to four wheel drive vehicles. With the exception of the recommended road closure, surface land use is presently not having significant impacts on Spirit Mountain Caverns.
- 6. Additional cave passages will probably be found in the general vicinity of Spirit Mountain Caverns. These passages will not necessarily connect with the presently known cave. Figure 22 shows a view of the Madison limestone cliff a few hundred feet north of any presently known entrances to Spirit Mountain Caverns. Figure 23 is a telephoto view of a portion of this same area. Figure 23 shows that there are a number of cave entrances in the limestone cliff. There are two pronounced entrances in the same stratigraphic position as the present entrances to Spirit Mountain Caverns.

In view of the maze type passage configurations common to the area, additional caves possibly could be found by entering exposed entrances such as those visible in Figure 23. Some of these caves could be significant. In view of the growing popularity of caving, it is anticipated that cavers will eventually begin climbing efforts to reach caves such as these; this sort of exploratory effort is already common in many areas of the U.S. As cave management in the area is considered, realize that the size and significance of the resource may be increased by discoveries. However, such discoveries bring increased management problems.



Figure 22. The Madison limestone cliff a few hundred feet north of all known entrances to Spirit Mountain Caverns. Entrances to unexplored caves are visible.



Figure 23. View of some of the unexplored cave entrances shown in Figure 22. The large upper entrance near the center could well lead to a significant cave.

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RECOMMENDATIONS FOR ADDITIONAL INVESTIGATIONS

As a result of the present investigations, several issues have been discovered which warrant further investigation. These are numbered and are briefly discussed below. Investigations 1, 2, and 3 should be conducted within the next year. In the case of investigations 4, 5, 6, and 7, these are recommended only if certain conditions are met.

- 1. One more set of alpha radiation measurements should be made in Spirit Mountain Caverns. Measurements should be made under warm weather conditions at stations 2 through 12. These data would be helpful in confirming the management recommendations relative to alpha radiation concentrations in this cave.
- 2. A moderately detailed search and rescue plan should be developed for Spirit Mountain Caverns. Such a plan would help insure prompt and effective search and rescue efforts.
- 3. A literature review showed that high concentrations of hydrogen sulfide gas apparently exist in some of the caves in the vicinity of Kane Cave (Egemeier, 1973). Some of these caves are apparently on lands administered by BLM. Hydrogen sulfide concentrations should be monitored in any of these caves administered by BLM, and this safety hazard should be evaluated at these caves.
- 4. Other caves will probably eventually be discovered near Spirit Mountain Caverns, and these caves might add significantly to the cave resource values present in the area. Any newly discovered caves should be assessed both for their features and for safety and management considerations as soon after discovery as possible. Prior to assessment, access to such caves should be very stringently controlled.
- 5. If people visiting Spirit Mountain Caverns in cold weather periods report the odor of hydrogen sulfide within the cave, monitoring of the concentrations should be conducted during cold weather conditions, and the possible hazard should be evaluated. We do not anticipate that significant concentrations of hydrogen sulfide gas will be encountered, but this recommendation is a prudent step.
- 6. During fieldwork some broken speleothem samples were collected for minerological evaluation. The samples are being evaluated by a minerologist; should he identify unique features in the specimens, additional evaluation might be desirable. His findings will be sent to BLM as an addendum to this report.
- 7. If appreciable cave use occurs during cold weather periods of the year, one set of alpha radiation measurements should be made during this period. It would be most desirable if the measurements were made at stations 2 through 12. If logistics problems made this difficult, measurements could be restricted to those stations on level 2 of the cave.

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APPENDIX A

Copy of the show-cave brochure for Spirit Mountain Caverns, with commentary and explanatory notes.

This appendix includes a copy of the show-cave brochure in use when Spirit Mountain Caverns was developed and open to the public. This brochure has historical value and this information should not be lost.

In our explanatory notes the location of many of the photos used in the brochure are identified.

The brochure includes several technical inaccuracies; these commonly appear in the public relations material issued by show-caves. First, the brochure states that the cave has a constant temperature of 54 degrees. Our measurements indicated a mean cave temperature of 45 degrees F. The brochure also reported that: "Some 8½ miles have been explored, and will be developed. It is believed, however, that many more miles exist, and await discovery". Based upon our work, the total known length of cave passage is somewhat less than one mile; additional discoveries are of course possible. Finally, the brochure reports that the cave tour is 3,400 feet long. We measured the length of the former tourist trail and found it to be approximately 800 feet long. Since tours retraced their route, the total distance traveled underground was about 1,600 feet.

Location of points photographed in the show-cave, Spirit Mountain Caverns

- Photo 1: View from the north of the Totem Pole, main (2) level.
- Photo 2: View looking northeast of Big Bridge, main level.
- Photo 3: Trail route between levels 2 and 3.
- Photo 4: Near the end of the trail, crystal level (3).
- Photo 5: Crystal level, near the pit at the end of the tourist route.
- Photo 6: View looking northeast at the top of the pit near Big Bridge, main level of the cave.

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Visit Wyoming's Spirit Mountain Caverns

THE LATEST NATURAL WONDERLAND OF WONDERFUL WYOMING . . .

- ONLY DEVELOPED CAVERNS IN WYOMING
- CONSTANT DRY TEMPERATURE OF 54 DEGREES
- 2260 FT. ABOVE THE MOST SCENIC 50 MILES IN THE WORLD
- COLORFUL FORMATIONS CAREFULLY ILLUMINATED

FROM CAVERN ENTRANCE



AT THE EAST ENTRANCE OF YELLOWSTONE NATIONAL PARK Wyoming's Newly Developed Spirit Mountain Caverns

On Highways 14 - 20



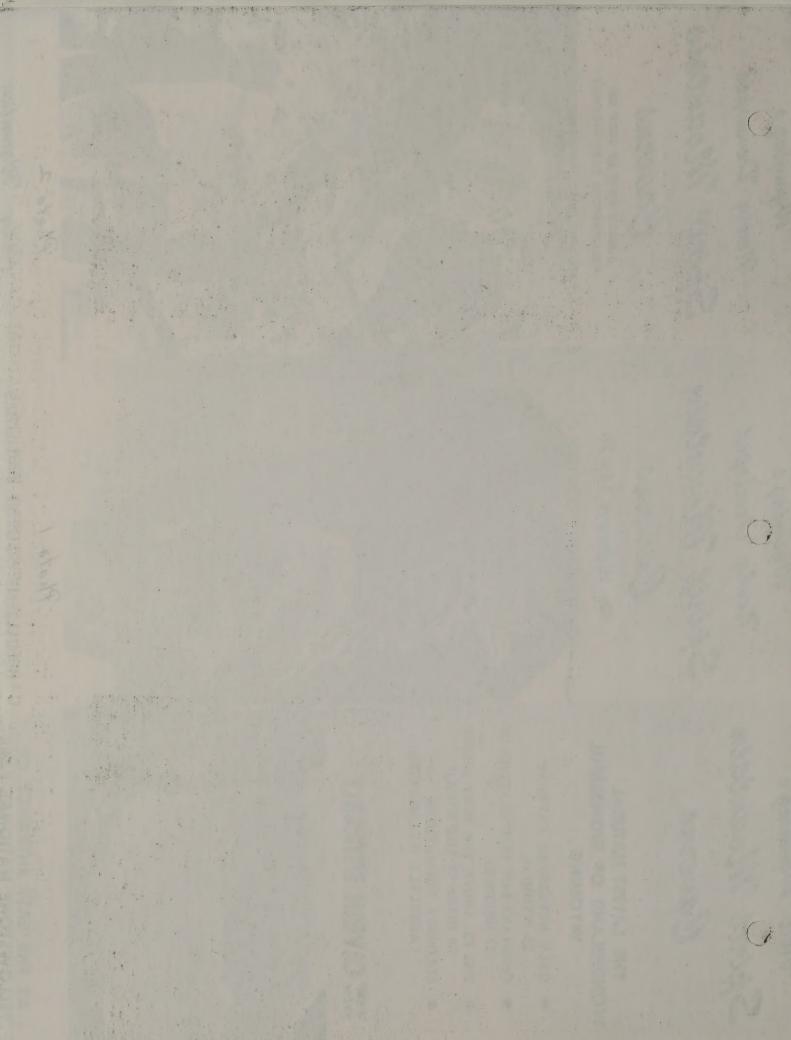
Photo /
EXCELLENT TOURIST FACILITIES

Wyoming's Newly Developed Spirit Mountain Caverns

> 2 MILES WEST OF CODY ON YELLOWSTONE PARK HIGHWAY



Photo 2 Cody, Wyoming



most scenic 50 miles in the world, have unknowingly been driving past one of the West's most fabulous cave

No longer will this natural phenomenon go un-noticed. Spirit Mountain Caverns, located nearly 3,000 feet above the scenic mountain highway, is now open to the public, offering all the splendor of millions of years of nature's handiwork.

Oddly enough, Spirit Mountain Caverns, located in Cedar Mountain just west of Cody, Wyoming, were discovered some 15 years before the Carlsbad Cavern discovery was announced to the world. The late Ned Frost, nationally-known big game hunting guide, discovered the caverns one frosty morning in November, 1908. The old-time trapper's hounds were in swift pursuit of a bobcat when they suddenly disappeared into the mountainside. Spirit Mountain Caverns, first appropriately named Frost Caves, had been discovered.

The caverns were later to be described by William H. Taft, President of the United States in these glowing terms: "A cavern in the State of Wyoming, of unknown extent but of many windings and ramifications and containing chambers of large size, magnificently decorated with sparkling crystals and beautiful stalactites, con-



Photo 3

are located only a few short miles from fabulous Yellowstone National Park. Probably a geyser or hot spring located side the cave sent warm air to the cave's entrance where, cooling rapidly, it became a vapor.

It took the determination of Claud E. Brown, president of Spirit Mountain Caverns Inc., to bring about the change necessary to make the caverns accessable to the public. Now, on a year around basis, the caverns may be visited.

Some of the outstanding features of the cavern and the surrounding areas are listed below:

- 1. Inside the cavern a carnival of color running from red to purple, blue to yellow, brown to orange, is not uncommon on the curious limestone formations making up the walls, ceilings and floors of the numerous chambers and galleries of Spirit Mountain Cavern.
- 2. Stalactites, stalagmites, calcite, crystals and other beautifully shaped forms of cave formations are present in the cavern.
- 3. An outstanding panoramic view of the sweeping western country near Cody can be seen from the cavern entrance. The view alone, is worth the trip to the cavern.
- 4. The cavern is situated only a few miles from Cody, Buffalo Bill's old hometown. In this picturesque little western city, excellent tourist facilities are located, as well as many items of scenic and historic interest.
- 5. Spirit Mountain Cavern is a few hundred yards off U. S. Highways 14 and 20, on a direct route to the Eastern entrance to Yellowstone National Park.
- 6. Just a few miles from the cavern, Buffalo Bill Dam and Reservoir holds thousands of fighting Rainbow trout. In addition, literally hundreds of miles of excellent trout fishing streams are found within several hours drive from the cavern entrance.

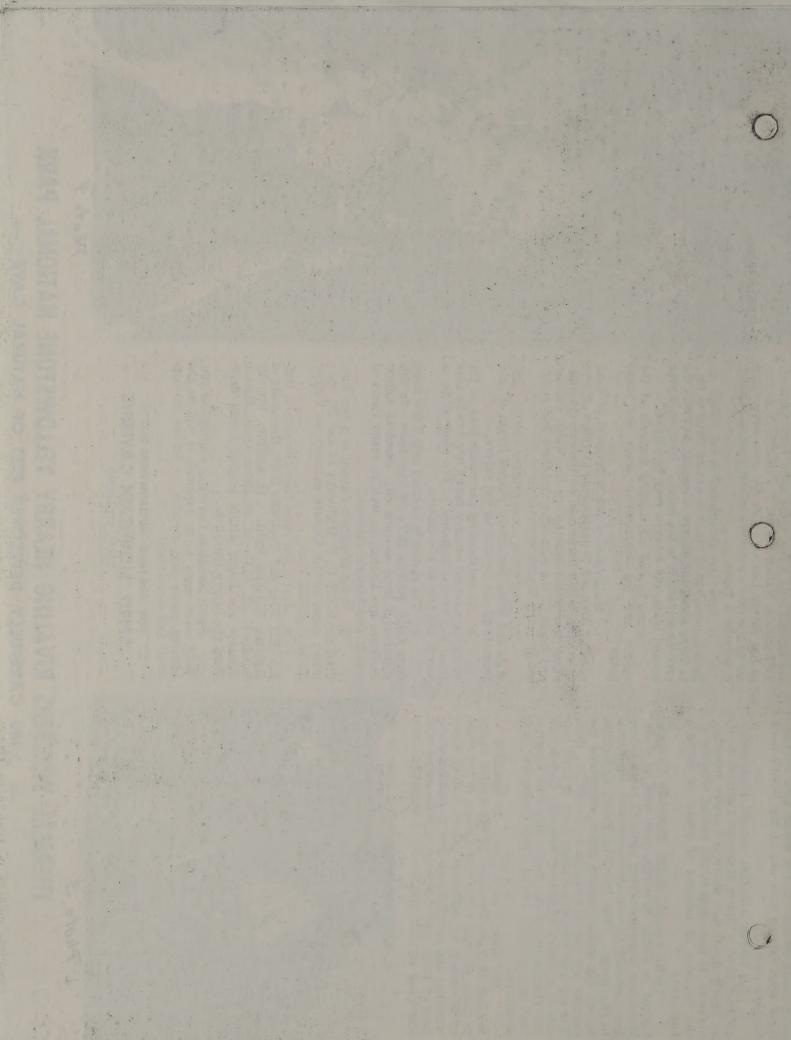
Spirit Mountain Cavern is waiting for you. With much more to be explored, it will be the visiting public that dictates its future development and discoveries.

SPIRIT MOUNTAIN CAVERNS
CODY, WYOMING



THERMAL WONDERS RIVALING NEARBY YELLOWSTONE NATIONAL PARK

3,400 CAREFULLY DEVELOPED FEET OF NATURAL CAVE -

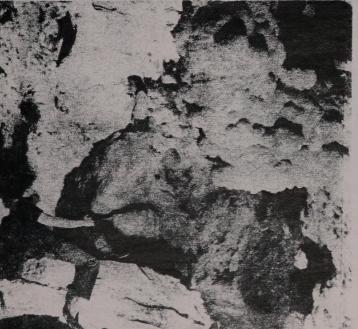


Visit The newly developed and most outstanding Natural Wonder of the West





2 MILES WEST OF CODY



Countless millions of visitors to Yellow-

Spirit Mountain Paverns Photo 5

taining impenetrable pits of unknown depths is of great scientific interest and value to the people of the United States." President Taft, in 1909, tried to make the caverns a National Monument.

To date, readily available for comfortable. dry exploring are 3,400 fabulous feet of Spirit Mountain Caverns, waiting to be viewed under carefully arranged lighting effects. Some 81/4 miles have been explored, and will be developed. It is believed, however, that many more miles exist, and await discovery. So, new discoveries will come as more "spelunkers" or cave explorers enter the cavern each year.

The huge cave, and Cedar Mountain, in which the cave is located, was known first to roving bands of Western Plains Indians as the dwelling place of a smoke breathing spirit. From time to time the superstitious redmen noted vapors and smoke-like mist rising from the side of towering Cedar Mountain. This gave rise to the belief among the Indians that a fire-breathing spirit lived inside the mountain. As a result, they named it "Spirit Mountain," and paid homage to the terrible spirit who lived there.

The theory today concerning the mist and



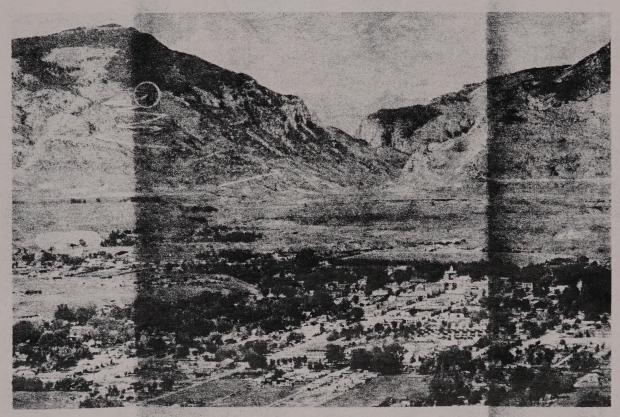


Fascinating Rock Flower Displays

Spirit Mountain Caverns

Picnic Areas On Way To Caverns

Educational
Entertaining
Mountain
Wonderland
of
Geology
Botany
Archeology



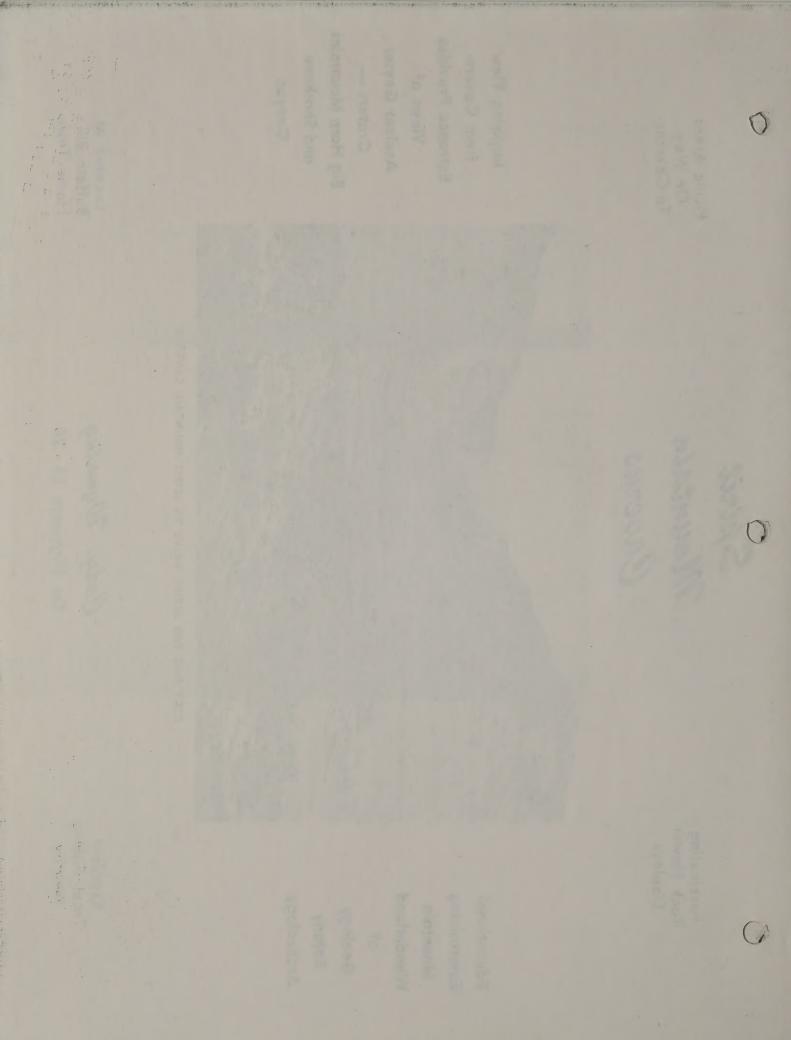
from Cavern
Entrance Provides
Views of
Ancient Geyser
Craters —
Big Horn Mountains
and Shoshone
Canyon

Inspiring View

CODY AND THE SCENIC DRIVE TO SPIRIT MOUNTAIN CAVERNS

Excellent Trout Fishing Nearby Cody, Wyoming
On Highways 14 - 20

Located at Buffalo Bill's Home Town



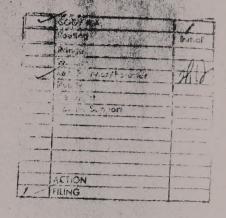
APPENDIX B

Correspondence between Thomas Enright and Warren C. Lewis, M.D. on histoplasmosis in Spirit Mountain Caverns.



WARREN C. LEWIN, M. D.
FRACTICE LIMITED TO INTERNAL MEDICINE
110 NORTH CHURCH TWEET
ROCKFORD, R. POUR SING!
TELEPHONE SERVEY

March 29, 1979



Mr. Thomas E. Enright
Cody Resource Area Manager
Bureau of Land Management
P.O. Box 528
Cody, Wyoming 82414

Dear Mr. Enright:

I wish to congratulate you for finding the spores of histoplasmosis in Spirit Mountain Cave. This is the first identification that I have heard of for your state. I can see that it poses a number of questions in your supervision of activities in the cave. Over the years I have been interested in the epidemiology of this disease. If you are interested, I would be glad to share with you some of the ways others have handled problems similar to yours.

Sincerely,

Warren C. Lewis, M.D.

WCL/jf

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Cody Resource Area P.O. Box 528 Cody, Wyoming 82414

April 5, 1979

Warren C. Lewis, M.D. 119 North Church Street Rockford, Illinois 61101

Dear Dr. Lewis:

Thank you for your letter and interest in the histoplasmosis problem we have in Spirit Mountain Cave. As you know, it has not been identified elsewhere in the state.

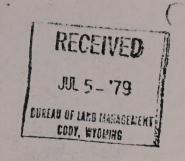
Our plans for the cave at this time are to assess the extent of the problem during the upcoming summer. We will be keeping the cave closed until we can determine how to handle the problem.

Any information you could supply us on how others have handled similar problems would be greatly appreciated.

Sincerely,

Thomas E. Enright Cody Resource Area Manager

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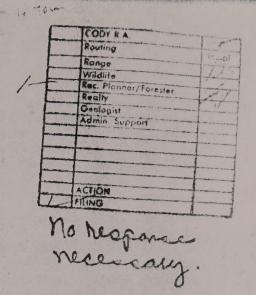
WARREN C. LEWIS, M. D. PRACTICE LIMITED TO INTERNAL MEDICINE 119 NORTH CHURCH STREET ROCKFORD, ILLINOIS 61101

TELEPHONE 963-1187

July 2, 1979

Mr. Thomas E. Enright Cody Research Area Manager P. O. Box 528 Cody, Wyoming 82414

Dear Mr. Enright:



Thank you for your continued interest in the problem of spores in Spirit Mountain Cave. Cave histoplasmosis is primarily a problem with heavily infected, bat infested tropical caves. A few reports are known from Continental U. S. cavers.

Twenty-five years ago histoplasmosis spores were found in two soil samples at the entrance of a cave in Maquoketa Caves State Park, Maquoketa, Iowa. As far as I can determine nothing was done by the authorities. Over a million people have visited these caves and picnic areas since that time. The 1972 attendance was 139,155. There have been no repercussions as far as I know from their policy.

Spores were also found in a large commercial cave in Southern ndiana.

Carlsbad Cavern has continued to operate as a popular tourist attraction although the cave contains spores. At least two individuals have been infected there. One was a New Mexico State archeolo gist and the other a United States epidemiologist from the Infectious Disease Center in Kansas City, Missouri.

While not connected with caves, numerous samples of soil from the parks in Washington, D. C. have been found to contain spores, yet this has not apparently interfered with the use of the parks. Infected wild caves are known in New Mexico, Texas, Missouri, Florida and Virginia among others.

In regard to foreign caves, a large commercial cave, Cacahuamilpa in Southern Mexico, has continued to operate in spite of two epidemics among tourists who left the tourist path. Aguas Buenas Cave in Puerto Rico was posted after an epidemic among school children and the finding of the spores in the cave soil. Several epidemics have occurred there among students of speleology. The caves remain open. The Cave of the Guacheros in Venezuela continues to be operated by the State as a State attraction, although spores have been found there. The Cave of the Owls (lachusas) in Peru has been posted to warn visitors of histoplasmosis. It has not been closed. Several wild raves in Trinidad have been left open as tourist attractions even chough they are known to be infected.

The Mayor of a village in San Luis P otosi, Mexico closed one cave that had been a source of infection. When a silt-blocked irrigation tunnel was being cleared at Colima, Mexico, the dirt was found to be infected. An epidemic developed in the workmen. The Institute of Health of Mexico stipulated that each worker should have a positive skin test before being allowed to work underground. This is a step that you might consider.

An article in a Canadian mining journal suggested that Canadian engineers wear masks when visiting tropical mines. This was the result of a rash of cases among Canadian engineers. They recommended a well-built mask with very fine pores. Such a mask is often bulky, is hard to keep in place and makes physical work difficult or impossible. After visiting an Aguas Buenas Cave, a doctor developed a positive skin test even though she was wearing a mask. Histoplasmosis has been cultured from masks worn by cave visitors in Panama. Masks give very poor protection.

Recently six cases of histoplasmosis have been reported from Madison, Wisconsin in those sawing wood. It would seem wise not to saw up wood that has been in the cave.

In Foreman, Arkansas, the opening of a partly artificial limestone cave was opened widely with a bulldozer by local officials. Most wild caves that are known to be infected have simply remained as they were. These continue to be visited by spelunkers and local adventurous people with only occasional mishaps.

A few attempts have been made to sterilize infected soil. A railroad carload of formaldehyde was sprayed over a five-acre tract in Cedar Rapids, Iowa. A year later viable spores were found beneath the top layer of soil. Needless to say any such application in a cave would have seriously harmful effects on other cave biota.

In employing individuals to work in the cave, you might consider employing young men who have grown up on a farm in Missouri, Arkansas, Kentucky or Tennessee. Eighty to ninety per cent of such young men will be positive because of previous exposure to histoplasmosis on their farms.

In the cave itself, digging should be kept to a minimum. Activities such as screening, sorting, carrying and dumping soil all increase the possibility of infection. These activities proved to be dangerous to those employed for the first time as guano workers. In consideration of this problem, though, one must consider that literally thousands of railroad carloads of bat guano were shipped infected from Texas caves to northern orchards without a public health problem becoming apparent.

In regard to cavers, if a young man has visited many caves he is likely to be immune. This likelihood is increased if he has visited caves outside his local area. It is increased if he has visited caves in the endemic area in the central part of our country or has visited tropical caves. In our country the primary spread is not from caves. Ninety-two per cent of the epidemics come from bird habitats. These range from blackbird roosts in Kentucky and Arkansas to a prairie chicken nesting area in Wisconsin and a gull rookery on Lake Huron. Birds themselves are apparently not infected.

You might be interested to know that a little brown bat has been found in Montana with histologic lesions of histoplasmosis. A cave in Southern Colorado is the seasonal home of 5000 Mexican Freetail Bats probably of the easternmost flight. This is the group of four strains of freetail bats which is most heavily infected. This Colorado cave also is the home of other bat species so cross infection is a possibility. Your cave is well within bat flight. Virtually every wild and domestic animal has been infected with histoplasmosis. In some species, such as foxes, it has assumed epidemic proportions. While bat infection of Spirit Mountain Cave is likely, it is not the only possibility.

In my opinion, you will be able to work in Spirit Mountain Cave with little danger to personnel by choice of workers and supervision of activity. In the past, such work has been done on occasion by cave clubs. Some have shown tremendous energy and initiative in projects such as yours. Members of such clubs willingly assume the responsibility of infection. It is my opinion that the presence of spores in your cave poses very little problem to the casual visitor. Light exposure rarely causes recognizable illness. I hope these comments will be of some assistance to you. It is my fervent wish that you will find a way to keep Spirit Mountain Cave open for the education and enjoyment of the public in years to come without endangering the public health.

Sincerely yours,

Warren C. Lewis, M. D.

WCL, M.D./ml

cc to Bill Mixon

APPENDIX C

Discussion of Cave Radiation

All caves contain some natural alpha radiation. The caves administered by the Bureau of Land Management are no exception. The purpose of this discussion is to give land managers an understanding of the issue, an assessment of the significance of the possible health hazard, and our recommendations for dealing with the issue.

General cave radiation information is included in this appendix so that it will not need to be repeated in three separate reports. Data on cave radiation which is specific to a particular cave is found in the text discussions about that cave; the reader should consult this material.

The cave radiation issue: Most people do not realize that there are varying levels of natural alpha radiation everywhere. Detectable concentrations can be measured out in the open air, in buildings, and in all caves. Natural alpha radiation occurs because there are small amounts of uranium and thorium in all rocks and soils. During the atomic decomposition of these materials, alpha radiation is produced.

Since alpha radiation is derived from materials in soil and rock, buildings made of earth and rock materials tend to have higher alpha radiation concentrations than buildings made of materials such as wood. Because they have less air exchange and more contact with soil and rock, basements and energy-efficient underground buildings typically have higher alpha radiation concentrations than above-ground buildings.

Alpha radiation can also be measured in caves, since caves are surrounded by rock and soil. Since natural radioactive materials are not distributed uniformly in soils and rock, and since air circulation patterns are not uniform in caves, alpha radiation concentrations may vary from point to point in cave systems.

Very high alpha radiation concentrations can be found in portions of uranium mines which are poorly ventilated. Medical studies of miners have indicated that exposure to alpha radiation increases the liklihood of eventually developing lung cancer. The greater the contact with alpha radiation, the greater is the possibility of eventually (perhaps in 20 or 30 years or so) developing lung cancer.

An obvious question is, why should alpha radiation increase the liklihood of lung cancer? Alpha radiation is a low energy ionizing radiation which can damage extremely delicate cells. Lung cells are extremely delicate, and they do appear to be damaged by alpha radiation. Although we do not know what causes lung cancer, it does appear that damage to lung cells (whether from alpha radiation, cigarette smoke, air pollution, or a host of other things) increases the liklihood of lung cancer.

There has been no research done to determine safe limits for exposure to natural alpha radiation. As we consider alpha radiation, it is important that we recognize it as a form of radiation which we cannot totally escape.

It is estimated that about 80% of lung cancers in the U.S. are related to cigarette smoking. Other lung cancers are related to asbestos and other carcinogens. Natural alpha radiation is well down the list of hazard factors.

Studies were conducted by the National Institute for Occupational Safety and Health on employees at National Park Service caves open to the public (these include Mammoth Cave, Carlsbad Caverns, and about half a dozen others). These studies did not show any correlation between employment in caves and increased occurrences of lung cancer. Since in medical research it is almost impossible to show that something is safe, these tests did not show that periods of cave work might not increase the liklihood of lung cancer by some small amount.

Aside from the research mentioned above, most of our insight into possible alpha radiation health problems comes from medical studies of miners. There are several reasons why alpha radiation as encountered in caves may be less hazardous than that encountered in mines. For example, mine air is contaminated by diesel smoke and dust, both of which are harmful to the lungs. In contrast, cave air is typically cleaner.

Significance of the human health risk: Although alpha radiation as encountered in caves may not be as harmful as alpha radiation as encountered in mines, it seems prudent to presume that it is. Based upon this presumption, we can use some of the rule of thumb values relating alpha radiation exposure in mines to the increased liklihood of lung cancer, and develop some numbers which will help place the cave radiation issue in perspective.

Let us assume that a "typical caver" takes five caving trips to BLM administered caves in a year. Let us further assume that two trips are to Horsethief Cave (where he spends a total of 20 hours), one trip is to Spirit Mountain Caverns (where he spends a total of 5 hours), and the last two trips are to La Caverna de Tres Charros (where he spends a total of 10 hours). This represents a total of 35 hours underground. Based upon mean alpha radiation concentrations measured at these caves, he would receive a total of 0.153 working level months of natural alpha radiation; his mean exposure rate would be 0.75 working levels per hour.

During the year that our "typical caver" does the caving outlined above, he will receive about 15% of his total alpha radiation exposure from BLM caves. The remaining 85% of his exposure comes from other environmental exposure; most of it is from living and working in buildings. At age 30, our "typical caver" would have received only about one

half of one percent of his total alpha radiation from his year of exploring BLM administered caves. The majority of his exposure would have been from buildings.

If we had 100 active cavers each year, and each of them followed the schedule of our "typical caver" and experienced similar radiation exposure from BLM caves, we should anticipate one excess lung cancer among this group every 875 years. Of course, this cancer might be curable. Based upon our "typical caver", we should anticipate one excess lung cancer for every 2.3 million man hours of caving in the three caves involved in our study.

If our "typical caver" lives in Laramie, his five cave trips in a year will represent about 3,500 miles of highway travel. Based upon national highway fatality statistics, there are approximately 3.4 fatalities in the United States for every 100 million miles driven. As low as this value is, the chance that the caver will be killed in a traffic accident on a cave trip is about 8 times greater than the probability that he will ultimately suffer a lung cancer from his year of caving in BLM caves. On a per hour basis, the chance of our "typical caver"

ultimately getting a lung cancer from exposure to cave air in BLM caves is about equal to the risk of being killed in the crash of a commercial Boeing 737 on a domestic flight. The Boeing 737 is the safest U.S. commercial airliner; this plane has experienced only 0.04 fatalities for every 100,000 hours of passenger flight time.

Among federal land management agencies, the National Park Service has been a leader in warning the public about hazards. The NPS (with the concurrence of the Environmental Protection Agency) does not view the cave radiation hazard as sufficient to justify warning of visitors at any NPS cave open to the public. During the course of a year, visitors to either Carlsbad or Mammoth receive a total alpha radiation exposure 400 times greater than that received from BLM caves by 100 active cavers following the schedule of our "typical caver". Medical research indicates that it is the total dose and not the rate of exposure which is important; for this reason the comparison of exposures between NPS and BLM caves is appropriate. Private show-caves and the National Park Service do inform employees about cave radiation; this is required under the precautionary cave radiation standards presently in force.

In an era where the word "cancer" carries panic connotations it is easy to react too strongly to a "newly discovered" potential hazard. It is our view that this is precisely what has happened with the cave radiation issue. As a result of overly reactive fears that caused a "caving causes cancer" campaign, cave management and cave safety efforts have been diverted away from things which are crucial, and have been concentrated on a risk which is minor in significance.

In Horsethief Cave, the cave radiation hazard can be compared quantitatively with the hazard of becoming so seriously lost that rescue is necessary. This comparison will further help to put the cave radiation hazard in perspective as a minor (and not a major) hazard.

The extensive portions of Horsethief Cave were discovered in 1970 (Sutherland, 1971). Within less than a year, one person was lost in the cave for 36 hours, and had to be rescued by cavers (Sutherland, 1971). In the BLM files in Cody we noted that a party of two people also became lost and required rescue a few years ago. Becoming lost and/or losing one's lights is a major hazard in Horsethief Cave.

Based upon data in the Cave Management Plan (BLM, 1978) visitation in Horsethief Cave is now limited to 400 people per year; this limit was based upon past usage. If we assume that the average trip in this cave lasts 10 hours, and that there have been 400 people per year visit this cave in the nine years since its discovery, then this represents a total of about 36,000 hours of cave use. Since at least three people have become lost and required rescue during this time, one person becomes lost for about every 12,000 hours of caving time. If we compare this value to the radiation hazard experienced by the "typical caver" spending 35 hours a year in three BLM administered caves, we derive a very interesting value. The risk of becoming lost in Horsethief Cave and requiring rescue is about 200 times greater than the risk that someone will ultimately experience lung cancer as a result of exposure to alpha radiation in BLM caves. To date, there have been no significant injuries or fatalities among those lost in Horsethief Cave; the people have been lucky. It certainly does not indicate that being lost is a harmless event.

Concern about cave radiation has diverted management attention away from more significant safety issues. This is clearly illustrated

by the above example. There are many other cave safety and cave management issues which are far more important and crucial than the cave radiation issue.

Finally, warnings to visitors should reflect a priority ranking which is related to risk. To do otherwise may result in visitors concentrating on trivial risks while paying less attention to major hazards. Furthermore, failure to adequately assess the magnitude of risks damages the credibility of the person and the agency giving the warnings; this can result in the visitor largely ignoring all warnings.

Management recommendations for dealing with the cave radiation issue: This appendix includes, as Attachment 1, the precautionary cave radiation health standards adopted by the National Caves Association. These are the standards which are currently in force for show-caves (commercial caves). There are no state or federal standards which apply to human exposure to alpha radiation encountered in caves. It is the policy of the federal Occupational Health and Safety Administration (OSHA) that federal operations shall be governed by health and safety standards no less stringent than those in force in the private sector. For this reason, the precautionary cave radiation standards which are enclosed are national standards and apply to federal agencies.

The precautionary cave radiation health standards (Attachment 1) are designed for show-caves which are open to the public. They are not specifically designed to cover undeveloped or "wild" caves such as those administered by BLM in Wyoming. However, the precautionary standards for show caves do provide extremely helpful guidance for managers of undeveloped caves. Our recommendations for dealing with the cave radiation issue rely heavily on the existing precautionary cave radiation health standards, and are compatable with them.

Our specific management recommendations are as follows:

- 1. Alpha radiation should not be considered as a major health and safety issue in cave management.
- 2. Based upon alpha radiation concentrations measured in Spirit Mountain Caverns and the fact that most visitation will be of short duration, we do not believe it is necessary for BLM to caution visitors to this cave about cave radiation. We estimate that the average visitor will spend about two hours in this cave. Based upon our measurements, the total amount of alpha radiation he will receive from this cave is approximately equal to that he would receive from spending four days in a building.
- 3. Based upon the low alpha radiation concentrations measured in La Caverna de Tres Charros, we do not believe it is necessary for BLM to caution visitors to this cave about cave radiation.
- 4. In view of the existing precautionary cave radiation standards and decisions by other federal agencies that visitors need not be warned about cave radiation at caves like Mammoth and Carlsbad, we do not believe it is necessary for BLM to caution visitors to Horsethief Cave about cave radiation.
- 5. Because visitors often spend long periods of time in Horsethief Cave, BLM might wish to bring the cave radiation issue to the attention of visitors to this cave. A possible wording for handout material for Horsethief Cave is in the health and safety considerations section of the Horsethief Cave report.

6. With respect to employees doing cave work, BLM should comply with the provisions of the precautionary cave radiation standards (Appendix 3, Attachment 1).

NATIONAL CAVES ASSOCIATION

Precautionary Cave Radiation Health Standards for Natural Caves Developed for Visitation by the General Public. Adopted April, 1978; Ratified November, 1978.

- 1. Where radiation monitoring is not done, underground work shall not exceed 700 hours per year for any employee.
- 2. Where radiation monitoring is done, annual cumulative radiation exposure shall not exceed 4.0 working level months of alpha radiation exposure for any employee.
 - A. Where monitoring is done, and adequate data have shown a seasonal repeatability in radiation concentration levels, professional scientific judgement shall be exercised as to the frequency of subsequent monitoring.
 - B. For monitored caves where the data base does not show a reasonable predictability in radiation concentration levels for the period being sampled, the following monitoring frequency will be used for monitoring occupied areas during those times when they are being regularly visited by employees:
 - 0 to 0.10 working levels: Annual measurement during that season when underground work time is greatest.
 - 0.11 to 0.20 working levels: Semi-annual sampling.
 - 0.21 to 0.30 working levels: Quarterly sampling
 - Over 0.30 working levels: Weekly sampling and record keeping on employee exposure accumulations.

Note: The working level range is based upon the average of the values obtained in a single sample set. The maximum average value on record should be used unless collected data suggest that this set is atypical. This table should be used flexibly by cave managers as a "sliding" scale linked with seasonal cave radiation variations.

- 3. Smoking in caves, either by employees or visitors, is prohibited.
- 4. Except as provided below, cave air shall not be used to ventilate buildings used by employees or visitors, nor shall cave air be allowed to freely enter such buildings:

Exception 1: Buildings which are used exclusively for entry to or exit from a cave are excepted.

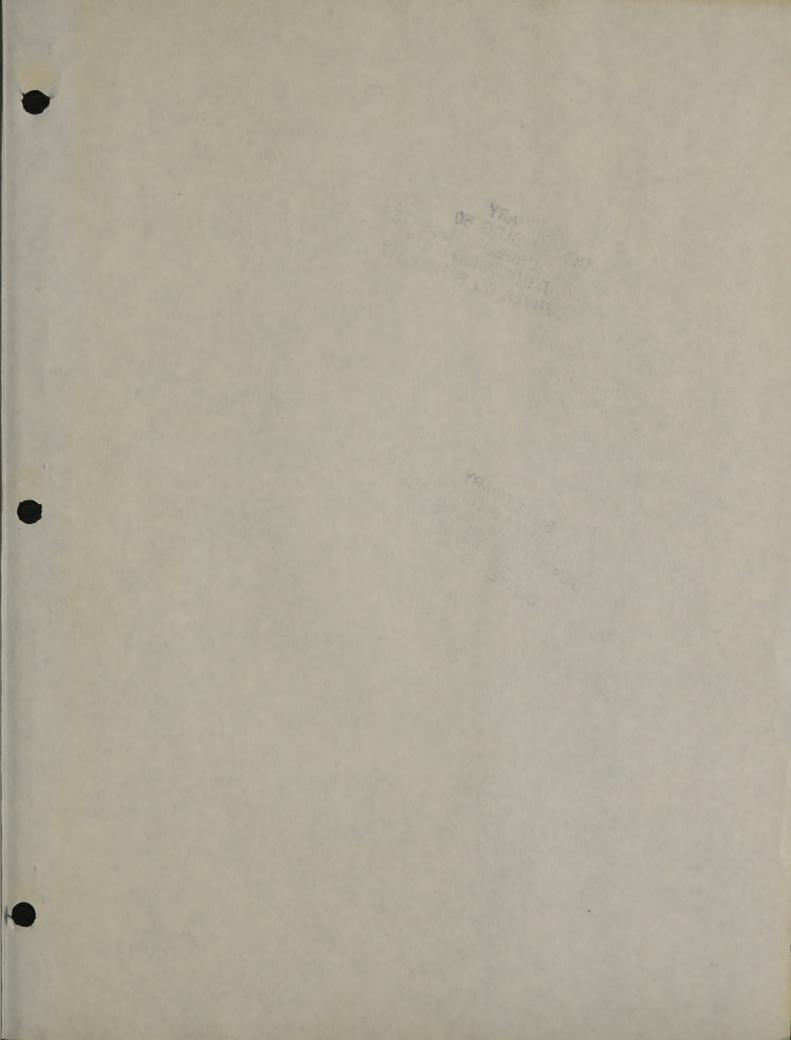
Exception 2: Buildings where no individual employee spends an average of more than 5 hours per week are excepted.

Exception 3: Buildings where radiation monitoring indicates that average alpha radiation levels are less than 0.10 working level are excepted. This applies regardless of whether radiation control measures are utilized in the building or not.

Exception 4: Buildings where radiation monitoring indicates that average alpha radiation levels are less than 0.30 working level are excepted if cave air was used for ventilation of this building during the summer of 1977.

5. The potential health hazard of alpha radiation in caves must be explained to all permanent employees who will be doing any underground work before they begin their employment.

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